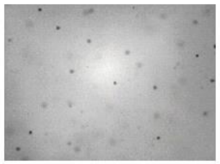
Scintillators in High Energy Physics

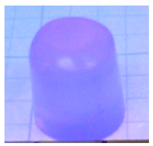
Hong Joo Kim
Department of Physics
Kyungpook National University

The 1st Particle Detectpr Workshop, Feb 6-7, 2026
IBS, Daejoen, Korea

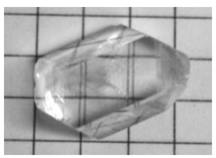
Scintillator



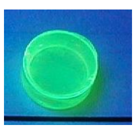
Inorganic semiconductor scintillator



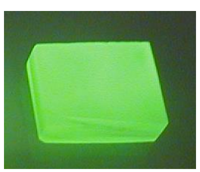
- Inorganic crystal scintillators



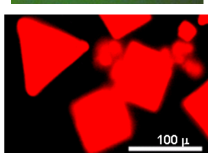
- Organic crystal scintillators



- Organic polymers, organic liquid



- Glass scintillator



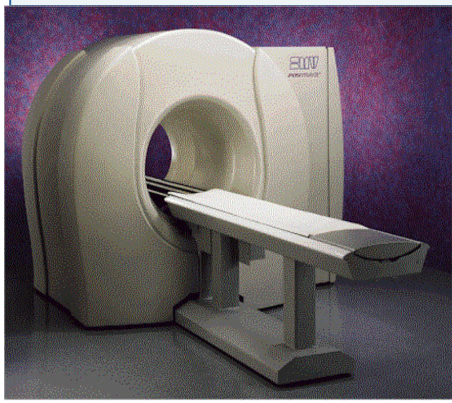
- Nanoparticle, glass ceramic

Scintillators

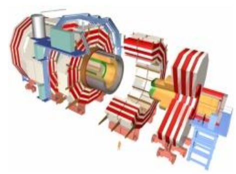
- Inorganic scintillators
  a) Result of crystalline structure
  b) Large band gap, insulators
  c) High light output
  d) high Z, high density
  e) Rather expensive, moderate size (~kg)
- Organic scintillators
  a) Molecular property of hidrocarbons
  b) Moderate light output but fast (~ns)
  c) low Z, low density
  d) Cheap, large size (~ton)
  e) Liquid scintillator (LSC)
  Plastic scintillator (PSC)
  Crystal (ex:anthracene, stilbene)

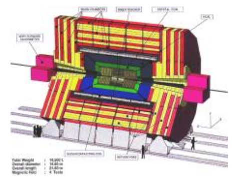
Application of Scintillators

Medical application



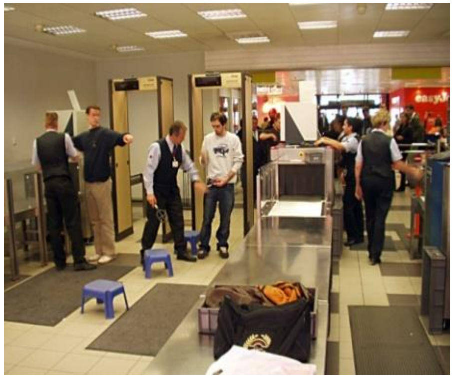
High energy and nucler physics





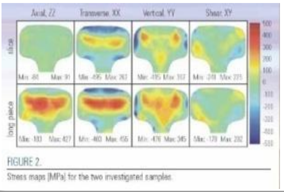
Astro-physics, ...

Security check

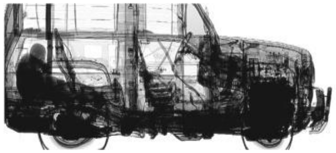


X-ray scanning

Nondestructive analysis



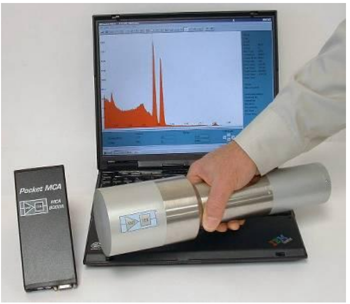
Board inspection



Radiation monitoring

Scintillation Detectors

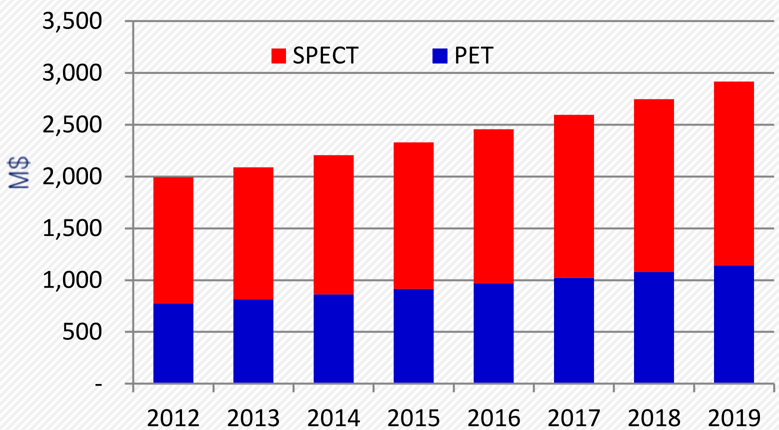
NaI(Tl) Spectrometer



Scintillation Surveymeter

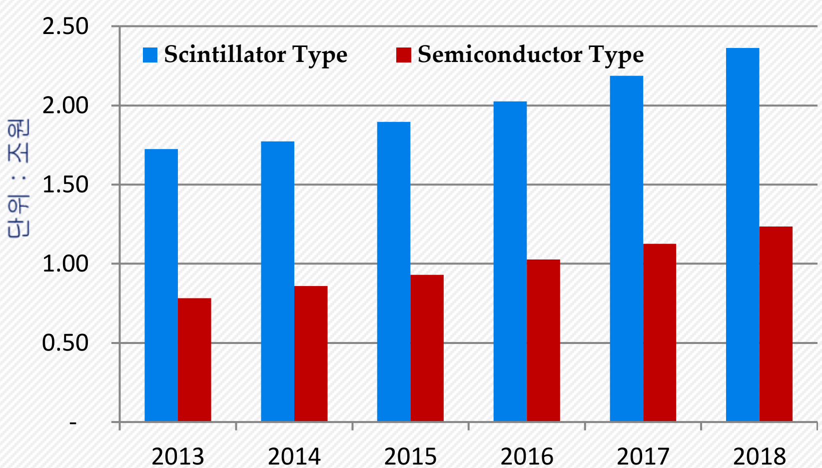
Scintillator supply

Medical Imaging market

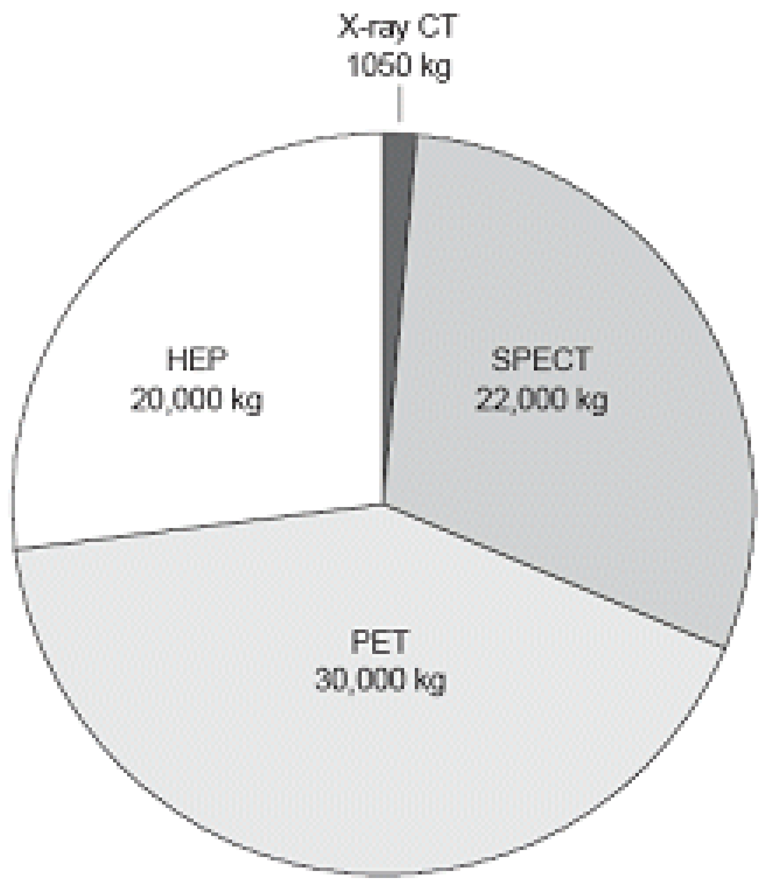


출처 : 의료기기품목시장리포트 Vol 14. 핵의학영상진단장치 (2013.6.30)

Radiation detector market



출처 : Radiation Detection Markets 2011 NanoMarkets



Crystal Scintillator market
Total 900 Millon $ (2003)

출처 : 서울대병원 핵의학과 이재성 교수님 자료

Scintillator Requirement for Applications

General requirements for scintillator applications

- ❑ High γ detection efficiency : high Z, high density
- ❑ Good energy resolution : high light output (LY)
- ❑ High count rate : fast decay time
- ❑ Cost : low cost material, easy to fabricate
- ❑ Background : low internal background

None of scintillator has best performance of every aspect
=> Scintillator should be optimized for each application

PbWO4 : very low LY but high density and fast τ –>CMS, CALET

CaMoO4, Li2MoO4 : low LY at RT, slow τ, no internal bg. -> AMoRE, CUPID

LYSO:Ce : High LY, fast τ, high Z, internal background, expensive -> PET

CsI:Tl, NaI:Tl : high LY, moderate τ, low background, cheap -> Belle, Fermi, KIMS, COSINE

LSC, PSC : fast decay time. moderate LY, low density, large volume : RENO, NEOS, RENE, JSNS, Daya Bay, JUNO, nEye so on (Talk by J.S. Lee, H.S. Lee)

Scintillator Development Direction

Invited Article

The quest for high resolution γ-ray scintillators

Pieter Dorenbos

Optical Materials: X 1 (2019) 100021

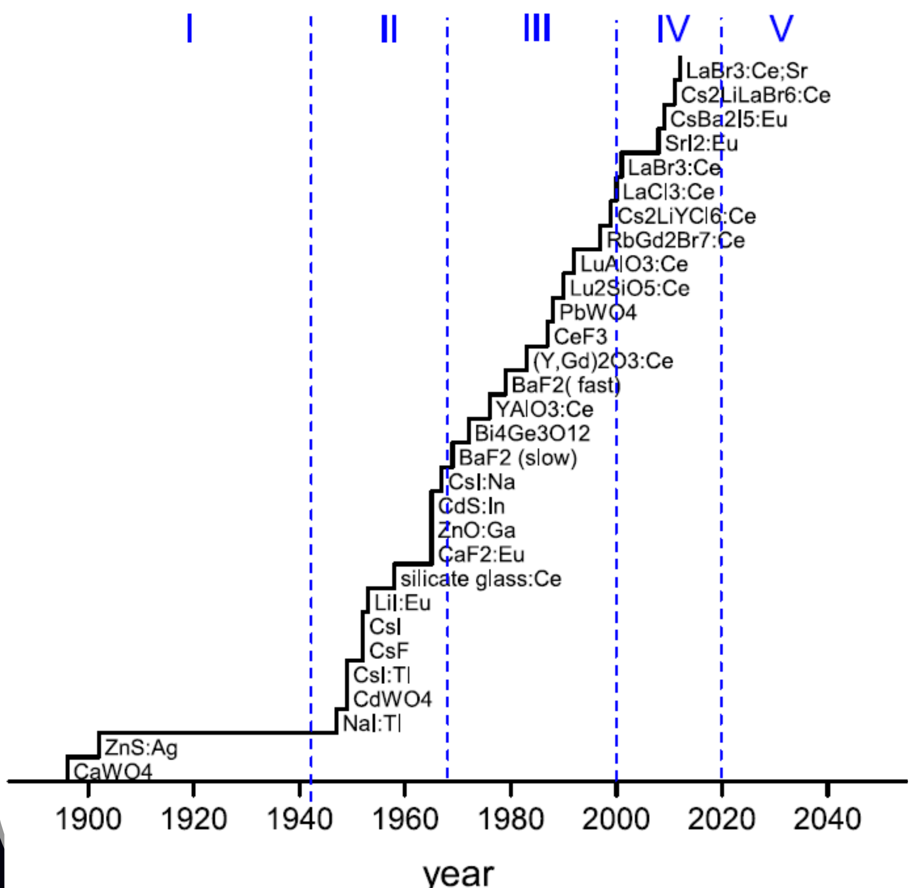


Fig. 2. History of scintillator discovery that distinguishes phases I to IV and phase V for future discoveries.

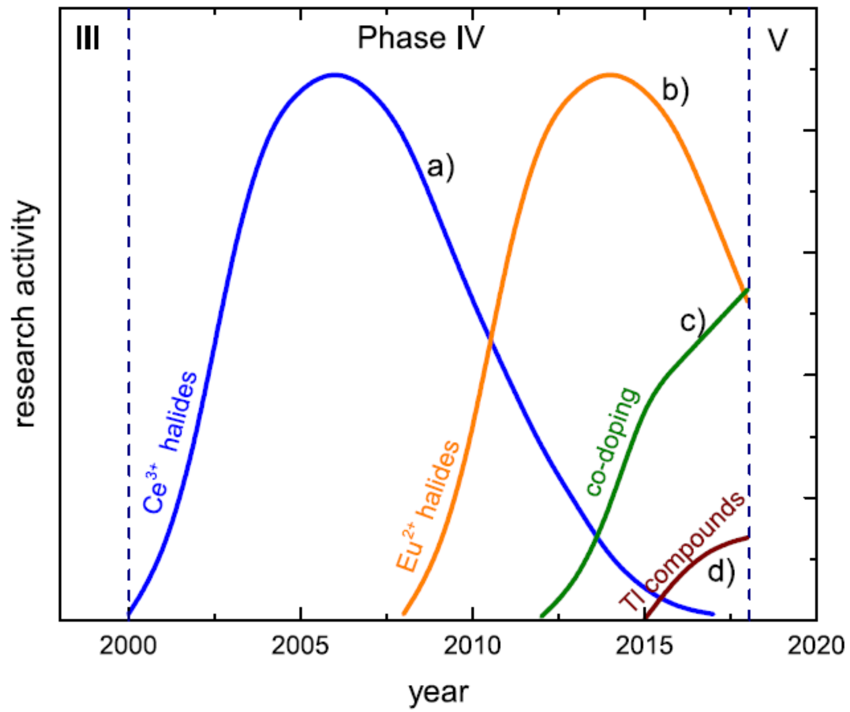


Fig. 4. Main lines of research during phase IV of scintillator discovery. a) The research on Ce^{3+} activated halide compounds inspired by the discovery of $LaBr_3:Ce^{3+}$, b) the research on Eu^{2+} doped halide compounds initiated by the re-discovery of $SrI_2:Eu^{2+}$, c) the increased research on co-doped scintillators stimulated by discovery of Sr^{2+} co-doped $LaBr_3:Ce^{3+}$, d) the research on Ce^{3+} activated Tl-based compounds initiated by $Tl_2LiGdCl_6$.

Discovered Tl-based novel scintillators

➢ The pioneer research work on the discovery and development of Tl-based scintillators was started in 2009 by our research group and published $Tl_2LiGdCl_6$:Ce as 1st paper in 2015.

Elpasolites

- $Tl_2LiGdCl_6$:Ce [1]
- $Tl_2LiGdBr_6$:Ce [2]
- Tl_2LiYCl_6:Ce [3-6]
- $Tl_2LiLuCl_6$:Ce [7]
- $Tl_2LiScCl_6$ [8]

Ternary Halides

- Tl_2LaCl_5:Ce [9-12]
- Tl_2LaBr_5:Ce [13]
- Tl_2GdCl_5:Ce [14, 15]
- $TlGd_2Cl_7$:Ce [16]
- $TlSr_2Br_5$ [17]
- $TlSr_2I_5$:Eu [18, 19]
- $TlCaCl_3$ [20]
- Tl_2HfCl_6 [21-24]
- Tl_2ZrCl_6 [25,26]
- $TlAlF_4$ [27, 28]
- $TlMgCl_3$ [29]
- $TlCdCl_3$ [30]
- $TlCaI_3$ [31]

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ORIGINAL PAPER

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Discovery, Crystal Growth, and Scintillation Properties of Novel Tl-Based Scintillators

HongJoo Kim,* Gul Rooh, Arshad Khan, Phan Quoc Vuong, and Sunghwan Kim

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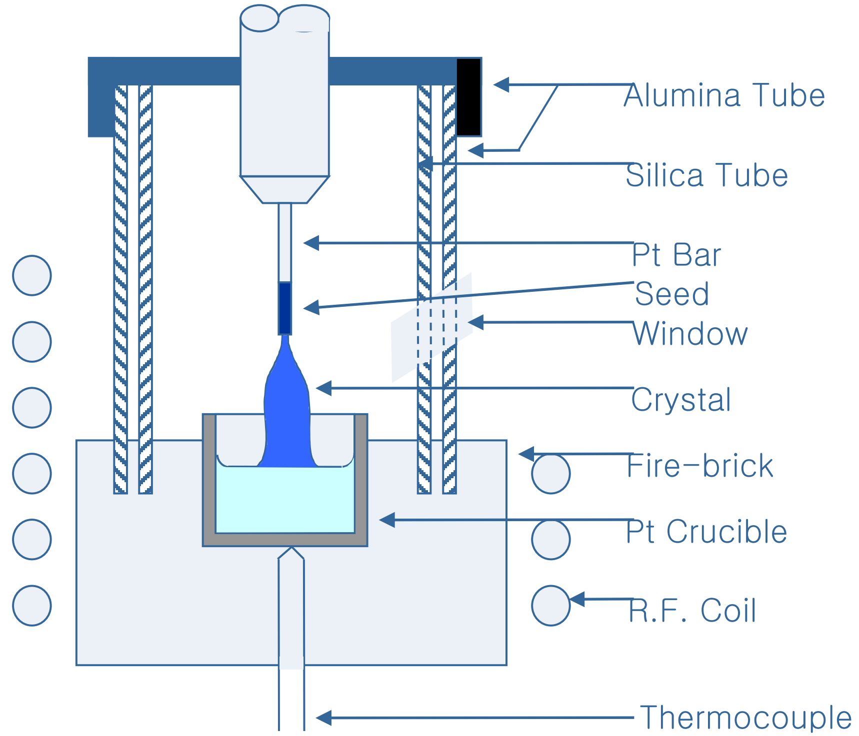
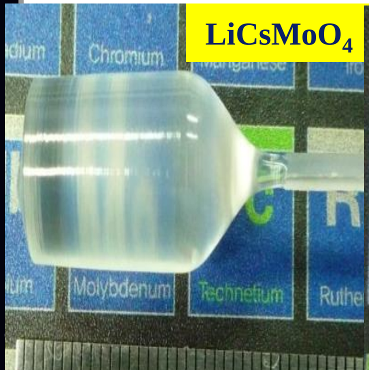
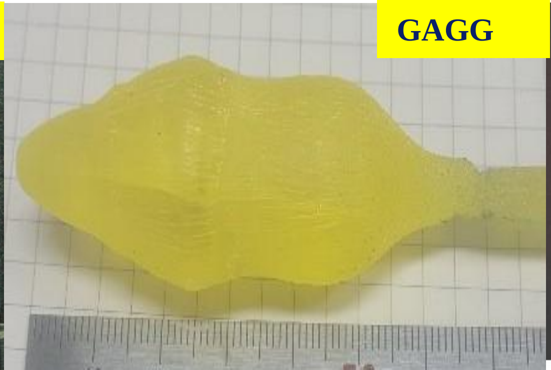
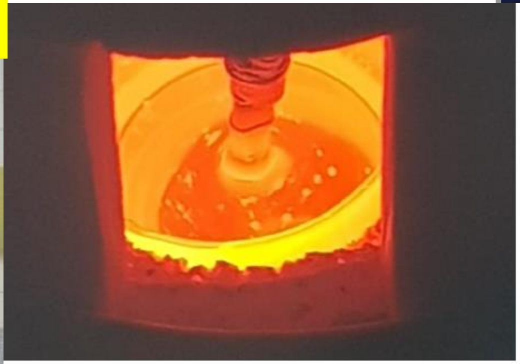
Crystal growing system with Czochalski method



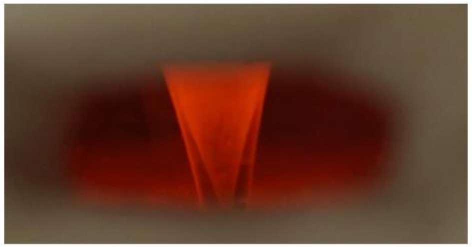
At KNU

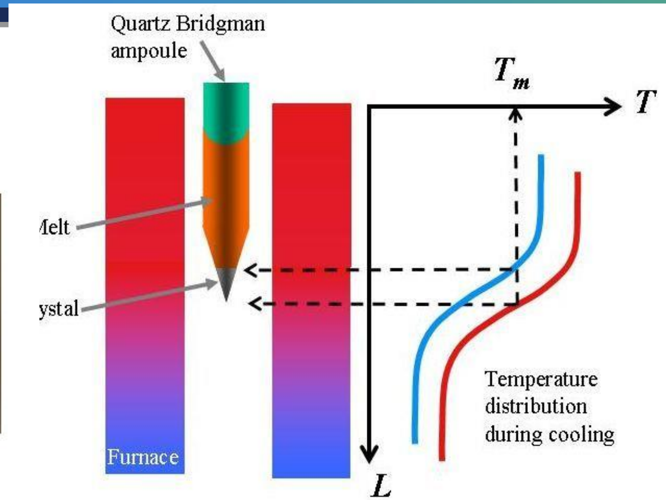




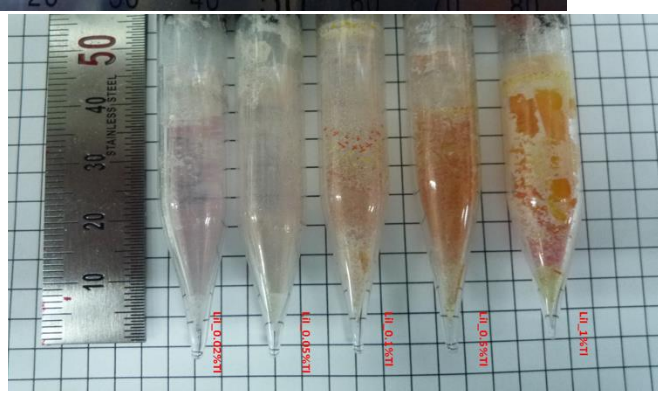


Bridgman Crystal Growing Methods

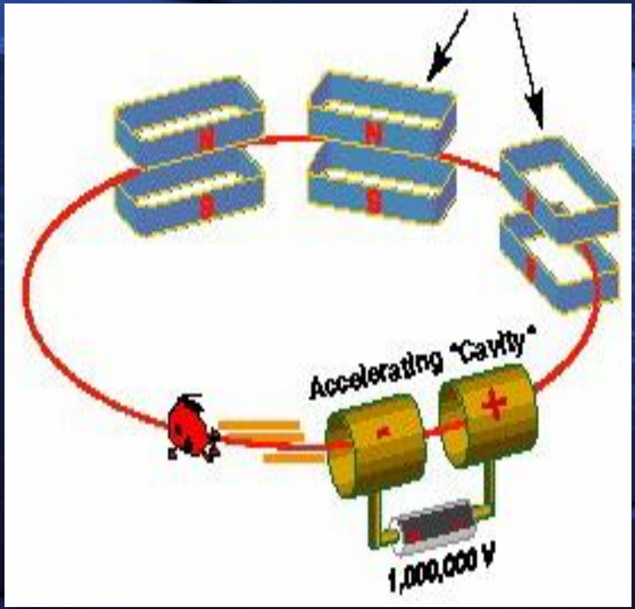

Crystal is growing in Bridgman furnace



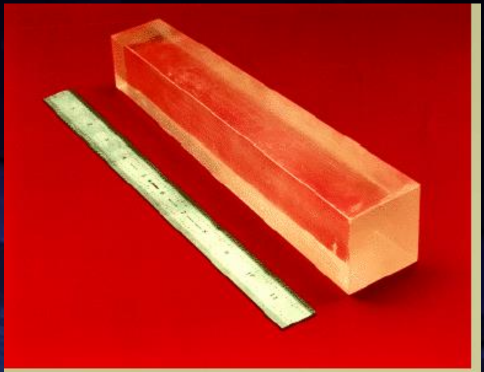
At KNU



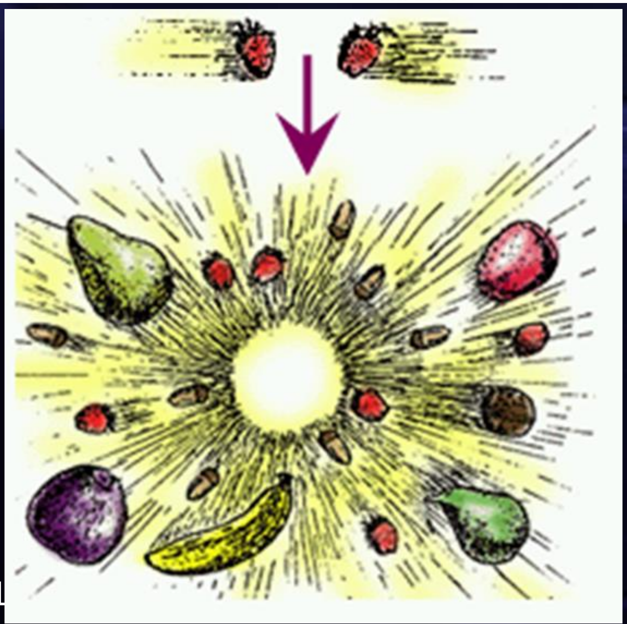
CsI(Tl) Calorimeter for High Energy physics

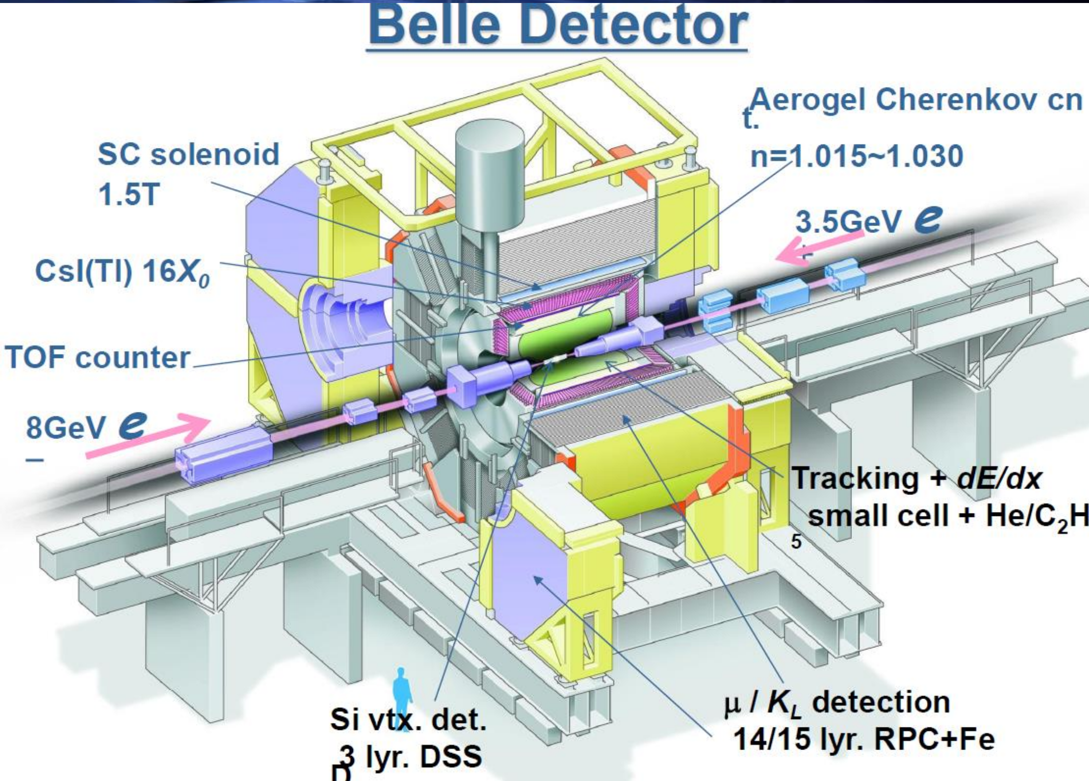


- B factory : Belle, Babar
  ~8000, ~20 ton
- Charm : CLEO, BESIII



- CsI(Tl) crystals, 30x5x5 cm (typic



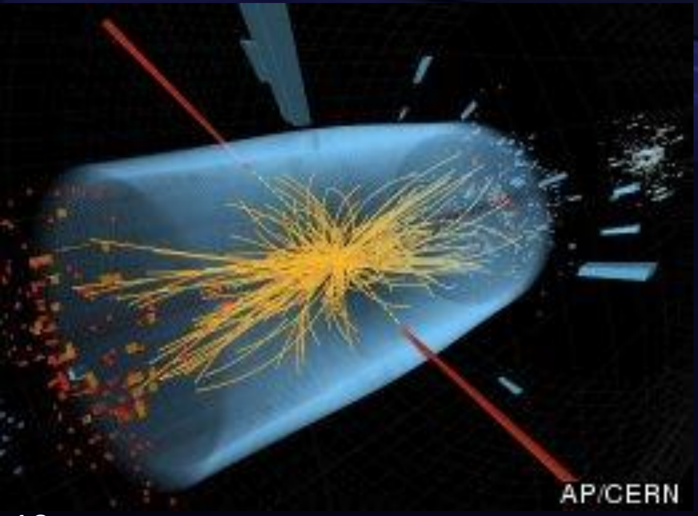


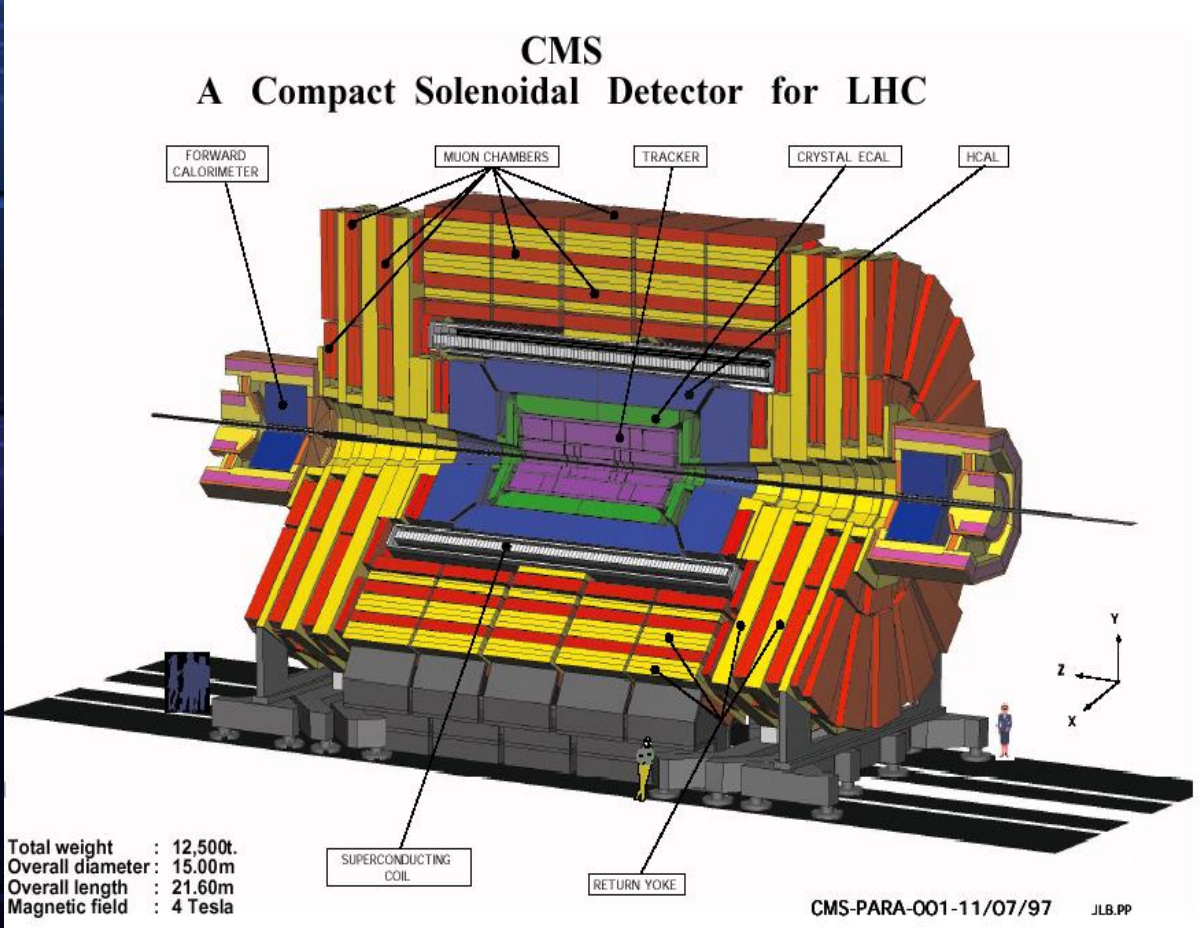
LHC(Large Hadron Collider)

Higgs boson found & nobel prize

7 TeV p + 7 TeV p
CERN

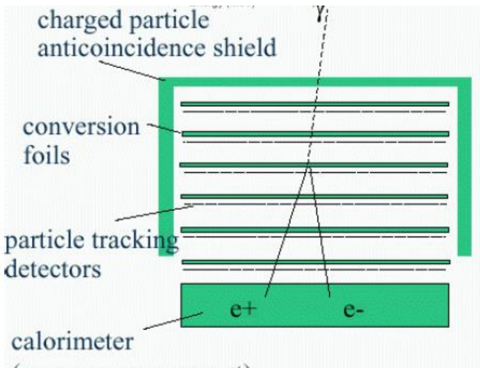
Total 90 ton

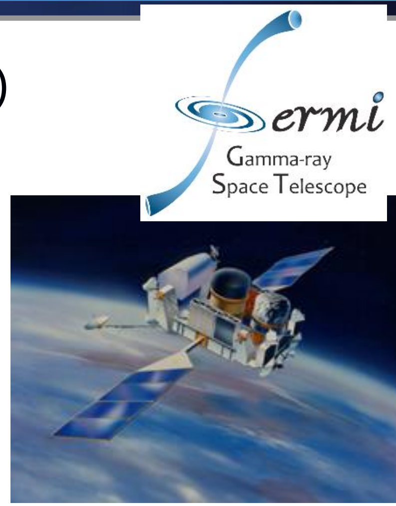


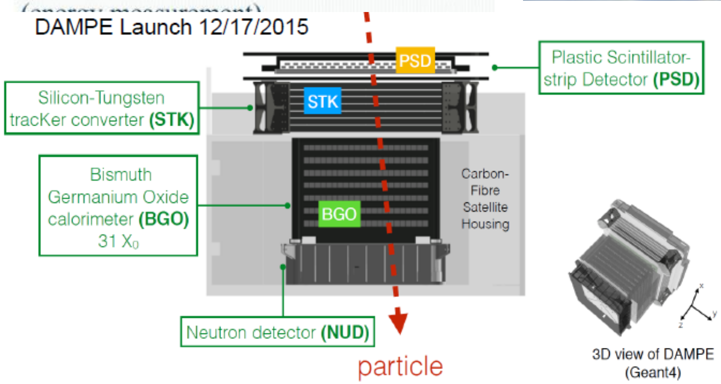


Calorimeter for astrophysics

FERMI (CsI:Tl, 8.6Xo)







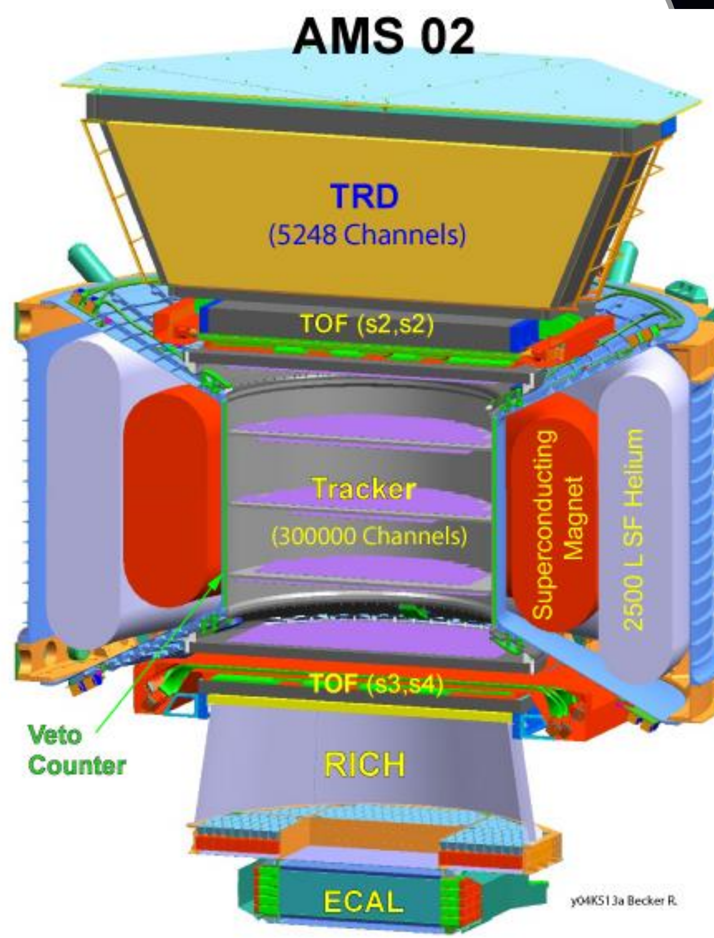


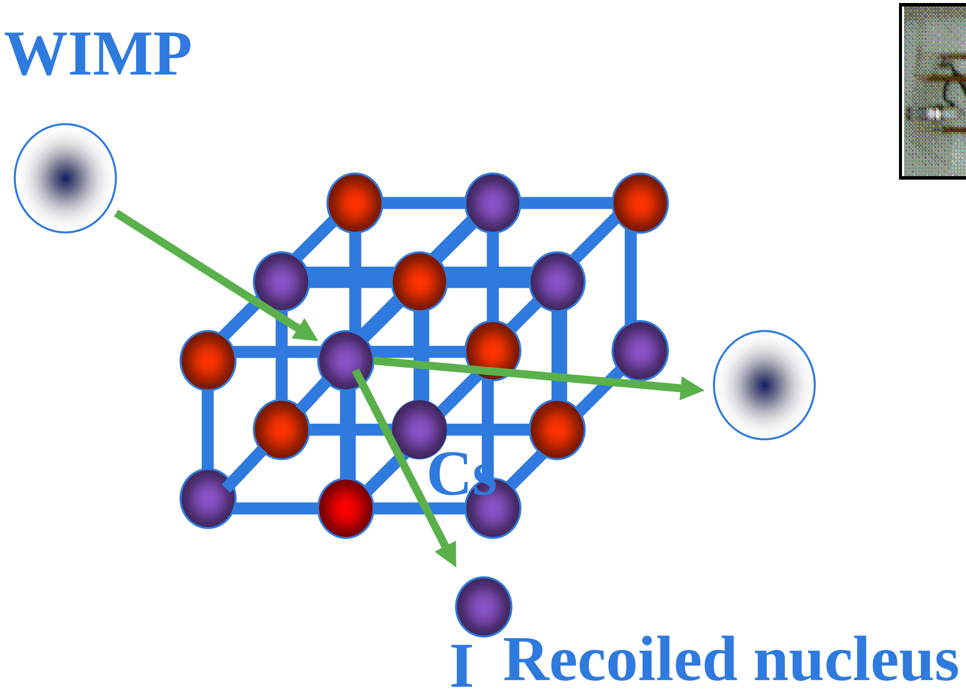
Table 1. Comparison of ISS-CREAM with other relevant space missions.

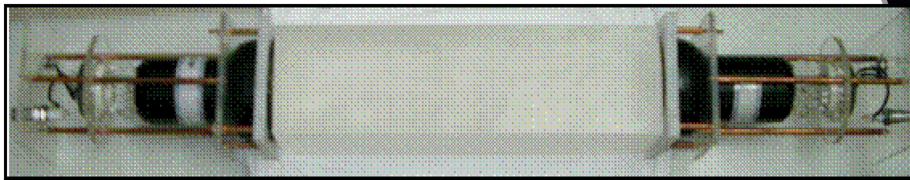
Project	Aperture (m^2sr)	Mass (kg)	Calorimeter thickness	Energy resolution electrons/nuclei	e/p rejection power	Charge Detector Type/resolution
NUCLEON	0.06	~300	16 X_0	10%/70%	~10^3	Si pad (3 x 1.5 cm^2)/0.3e
ISS-CREAM	0.43	1258	20 X_0, 1 λ_0	5%/40%	5×10^5 @50% eff.	Si pad (1.37 x1.55 cm^2)/0.2e
CALET	0.12	613	27 X_0, 1.35 λ_0	2%/ Not Avail.	10^5 @80% eff.	Plastic Scin. strips/0.35e
DAMPE	0.2-0.3	1400	33 X_0	1.5%/40%	~10^5	Plastic Scin. strips/0.25e
GAMMA-400	1 m^2 area	4100	~25 X_0, 1.1 λ_0	1%/ Not Avail.	5×10^5	Plastic Scin. Strips/ Not Avail.

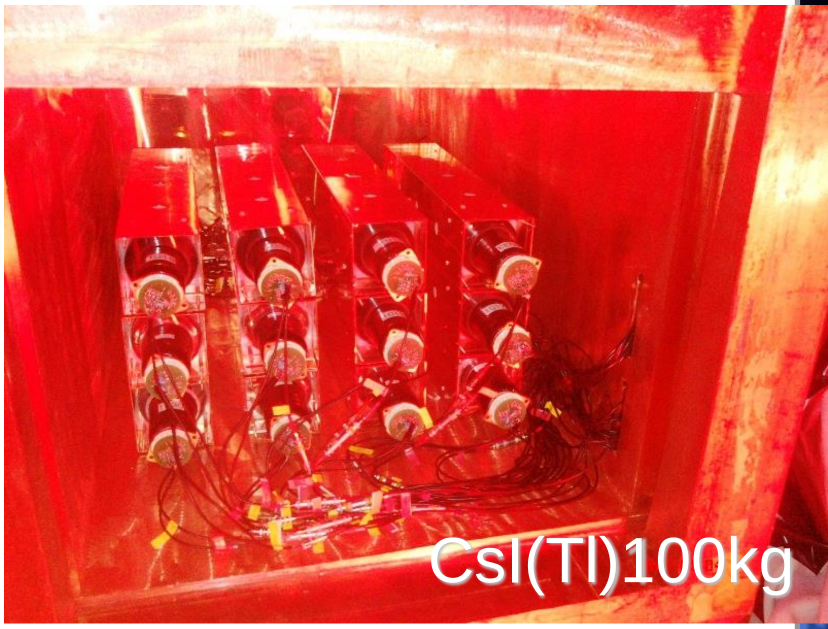
CsI Detectors Photo-Diode sens

Dark matter Search (KIMS)

Elastic Scattering of WIMP off a nucleus in the detector







Energy loss by ionization(scintillation) and lattice vibration

Leaded by S.K. Kim, first PRL by H.S. Lee

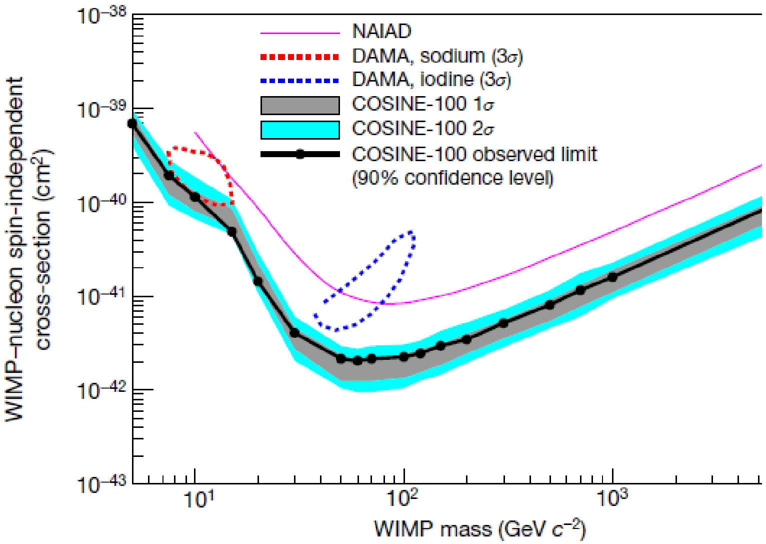
LETTER

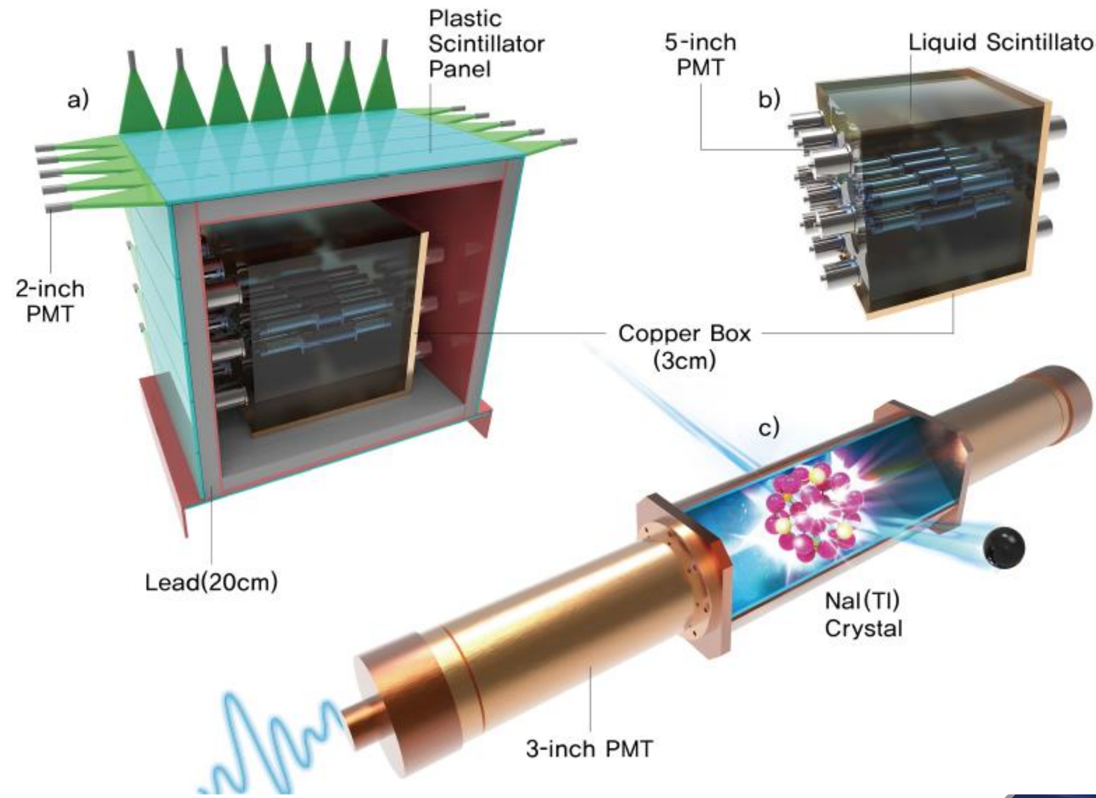
Nature

https://doi.org/10.1038/s41586-018-0739-1

An experiment to search for dark-matter interactions using sodium iodide detectors

The COSINE-100 Collaboration*





Talk by H.S. Lee

AMoRE-II: Mo crystals grown and tested

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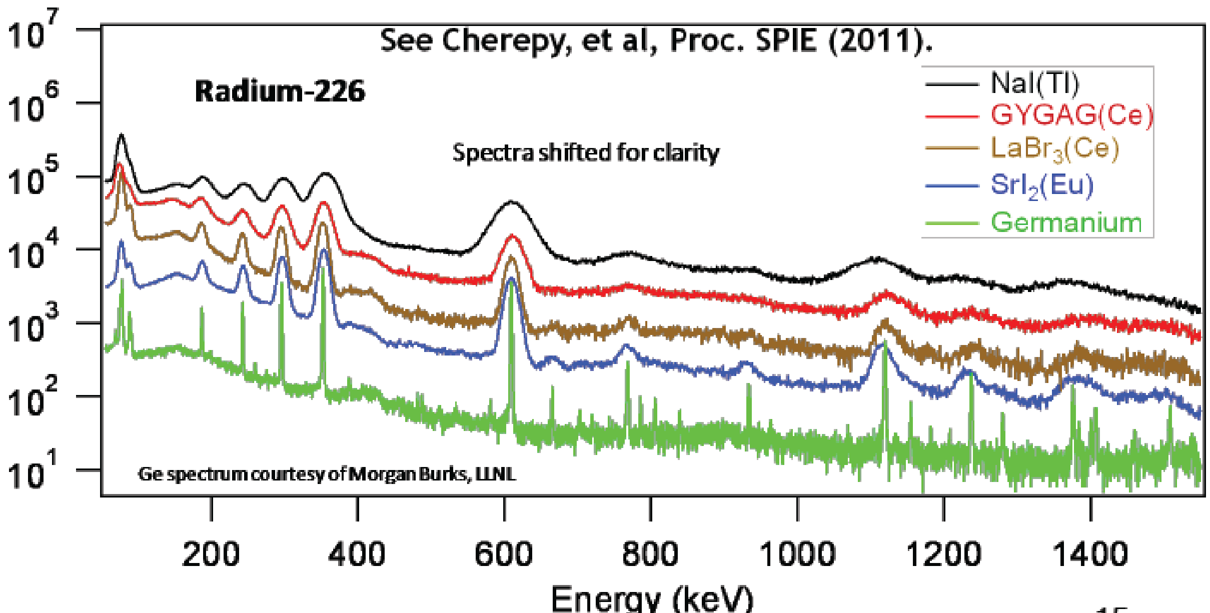
Search for New Molybdenum-Based Crystal Scintillators for the Neutrino-Less Double Beta Decay Search Experiment

HongJoo Kim, Indra Raj Pandey, Arshad Khan, Ju-Kyung Son, Moo Hyun Lee,* and Yeongduk Kim*

X-ray and gamma spectroscopy

Radiation Monitoring
1)Near Nuclear reactor
2)Accelerator beamline
3)Cancer treatment with gamma, x-Ray
4)Envirnmental radiation monitoring



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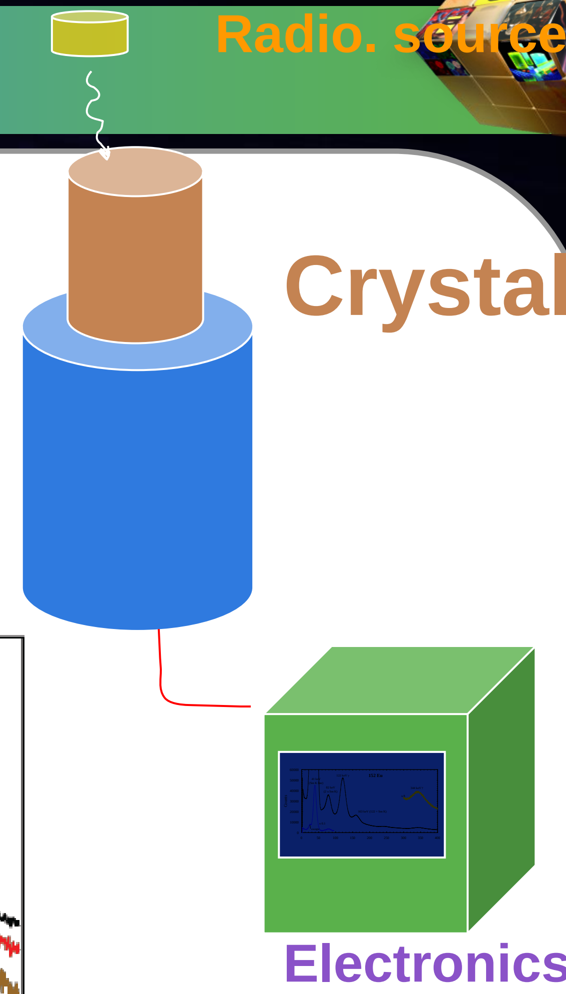
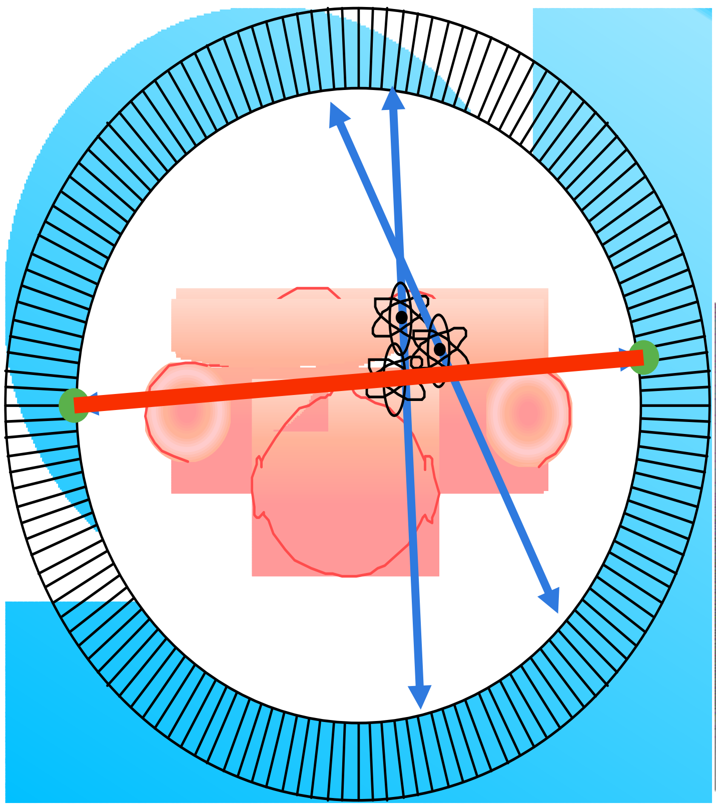


Positron Emission Tomography (PET)



POSiTRACE

Dual Mode PET/CT Oncology System

- Detects Pairs of Back-to-Back 511 keV Photons
  - No Collimator Needed $\Rightarrow$ High Efficiency

Buying vs Cooking : What to do?

You want to buy scintillators if they are available and meet your requirement.

You have to do R&D for new scintillators since company can not do R&D for you or will not do it unless you pay big money. Talk of new receipt by C.H. Ha

Ex : Many Molbydate crystals for AMoRE, InI, Radioactive doped $CeBr_3$

Why we need common detector R&D facility?

You want to do R&D with experienced people and staff

You want common scintillator R&D facility where more equipment and characterization tools are available.

https://scint2026.knu.ac.kr/

SCINT 2026
GYEONGJU, KOREA

18th International Conference on
Scintillating Materials and their Applications

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Jungho So (IBS)
Jung-Yeol Yeom (KU)

Main Topics

- Mechanisms and theory of scintillation
- Characterization of scintillators
- Crystal growth and structural control
- Optical ceramics and glasses
- Nano- and metamaterials, hybrids, organic, and liquid scintillators
- Scintillators for fast-timing detection and imaging
- Scintillators for neutron detection and imaging
- Applications of scintillators in fundamental research, health, environment, energy, metrology, and industrial controls