^{48}Ca Enrichment by using Crown-Ether Resin

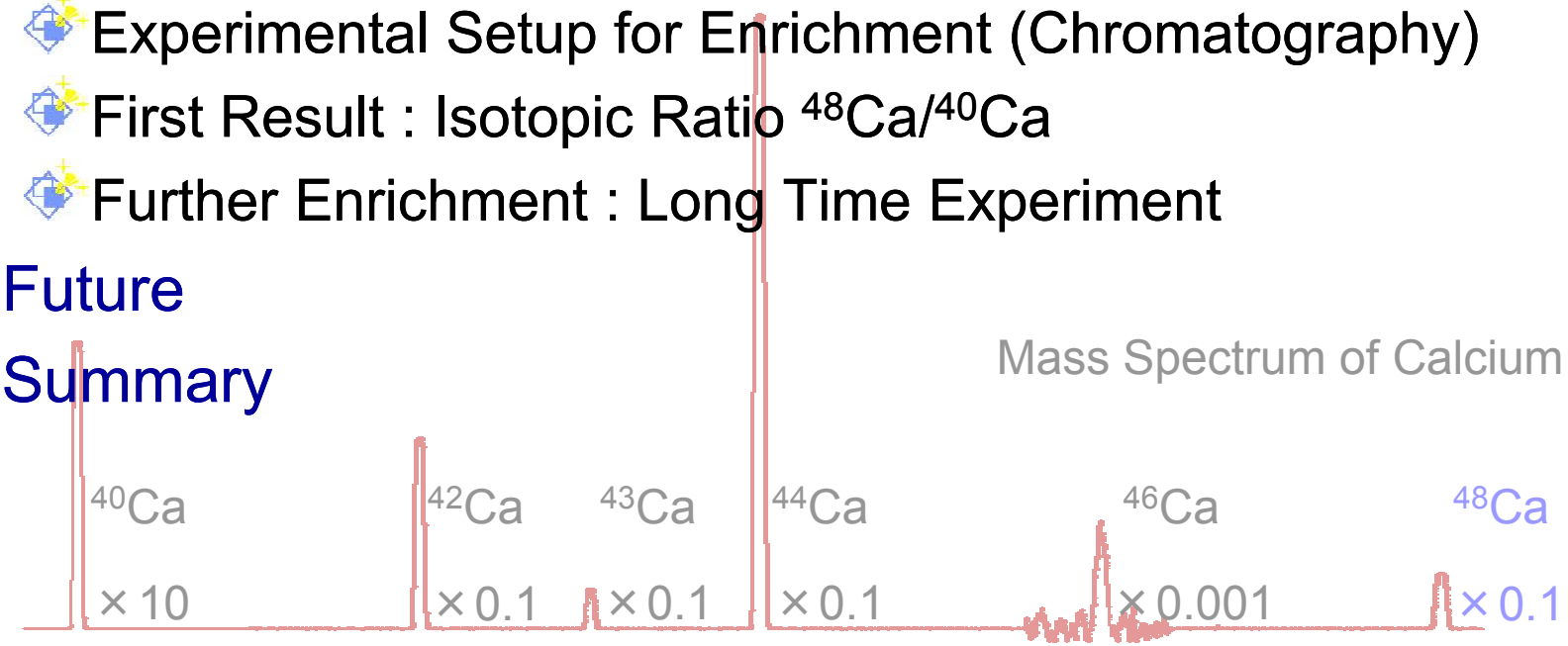
UMEHARA Saori
umehara@km.phys.sci.osaka-u.ac.jp

H. Kakubata, T. Kishimoto,
S. Nemoto, M. Nomura, T. Kaneshiki, T. Suzuki,
Y. Sakuma, Y. Fujii,
CANDLES collaboration

Osaka University,
Tokyo Institute of Technology,
Sophia University

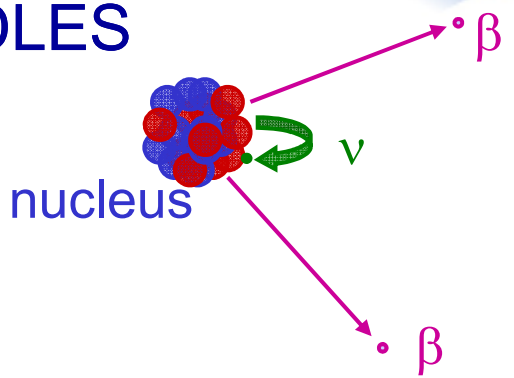
Outline

- Double Beta Decay of ^{48}Ca by CANDLES
- Enrichment of ^{48}Ca
- ^{48}Ca Enrichment by using Crown-Ether Resin
  - Crown-Ether
  - Experimental Setup for Enrichment (Chromatography)
  - First Result : Isotopic Ratio $^{48}Ca/^{40}Ca$
  - Further Enrichment : Long Time Experiment
- Future
- Summary



Double Beta Decay of ^{48}Ca

- Double Beta Decay of ^{48}Ca by CANDLES
  - CANDLES System
    - CaF_2(pure) Scintillators



^{48}Ca

Higher $Q_{\beta\beta}$-Value(4.27MeV)

→Lower Background

because $Q_{\beta\beta}$-value is higher than BG

E_{max}=2.6MeV(^{208}Tl,γ-ray)、

3.3MeV(^{214}Bi,β-ray)

. . .but smaller Natural Abundance

	Natural Abundance
^{40}Ca	96.941%
^{42}Ca	0.647%
^{43}Ca	0.135%
^{44}Ca	2.086%
^{46}Ca	0.004%
^{48}Ca	0.187%

Enrichment of ^{48}Ca

for Study of ^{48}Ca $0\nu\beta\beta$ by CANDLES

It needs a large amount of ^{48}Ca(~10kg)

→1st Step : Large scale detector : CaF_2 of 300kg ~ a few ton

→2nd Step : ^{48}Ca enrichment（~2%~）

Technologies for ^{48}Ca Enrichment

Gas diffusion 、、、 × ⟸ Calcium =

Gas centrifuge 、、、 × No Gaseous Compound

Chemical process 、、、 ○

Chemical process

⇩ ← Production capacity、Cost

Ca enrichment

by using crown-ether

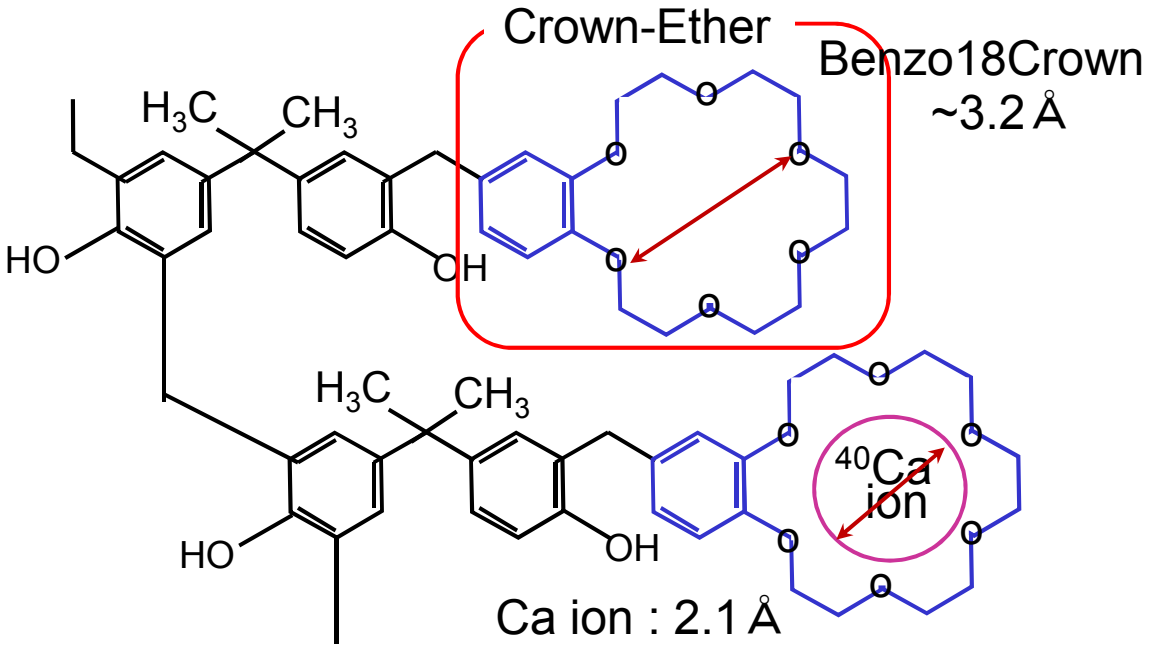
Crown-Ether

Isotope Enrichment by Crown-Ether

- Crown-ether rings adsorb Calcium ions
- For calcium, ^{40}Ca adsorption in crown-ether is slightly prior

Crown-Ether Resin

Benzo-18-Crown-6-Ether

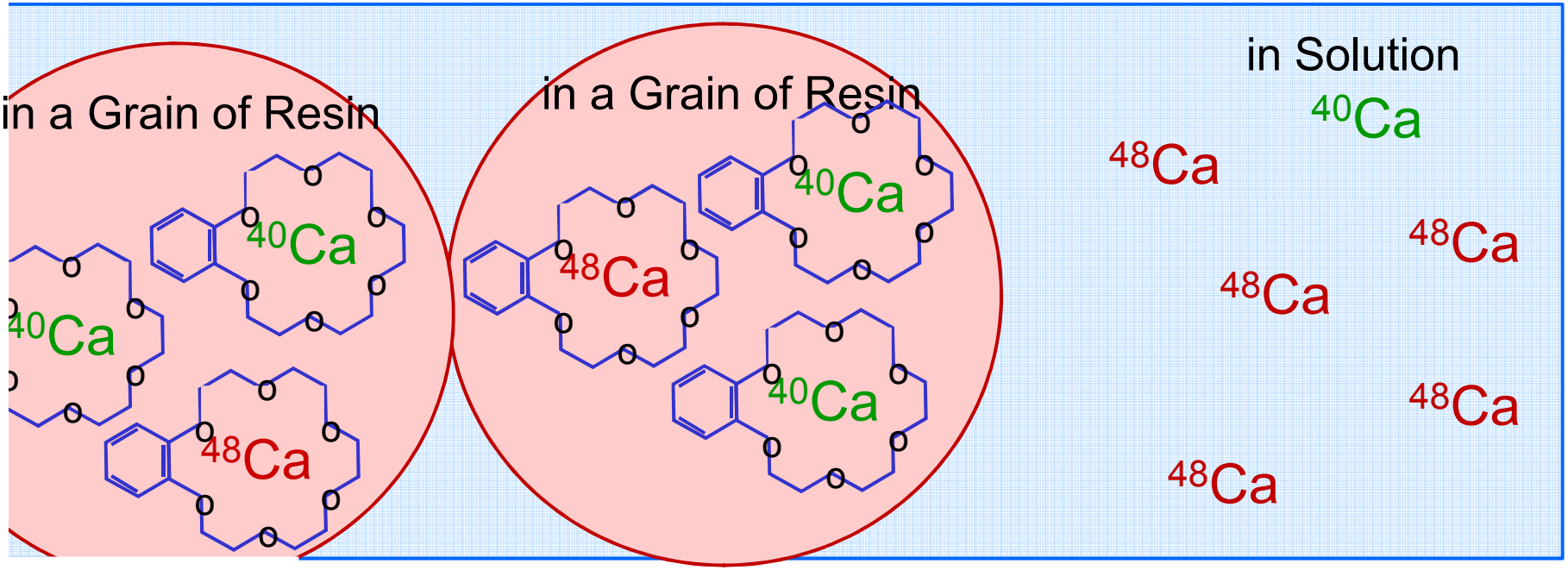


Enrichment by using Resin

Isotope Effect by Crown-Ether Resin

Ca solution

Migration in Resin area . . . ⇩ ^{40}Ca adsorption is slightly prior



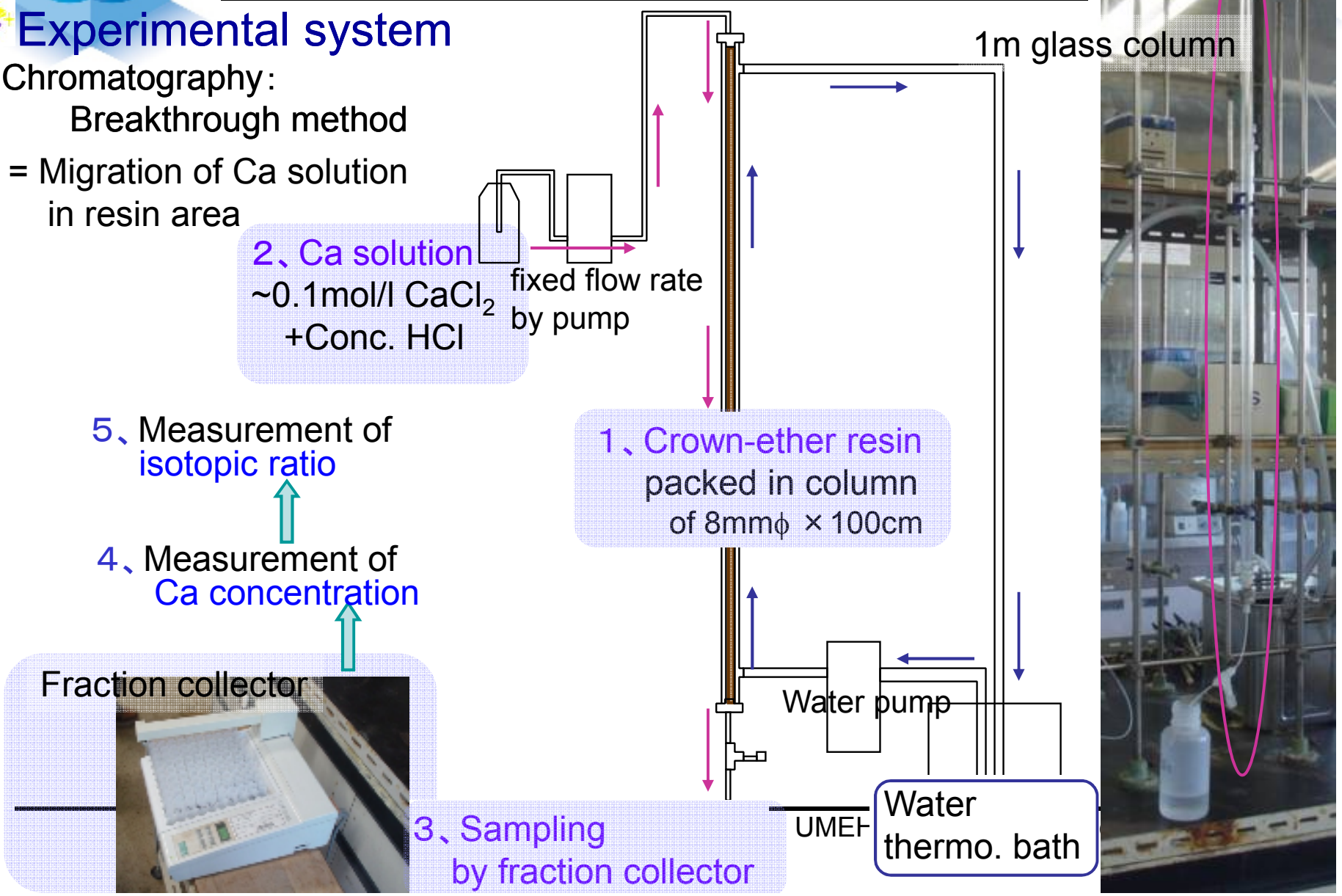
Resin phase : ^{40}Ca is enriched

Solution phase : ^{48}Ca is slightly enriched

Experimental Setup

Experimental system

Chromatography:
Breakthrough method
= Migration of Ca solution in resin area

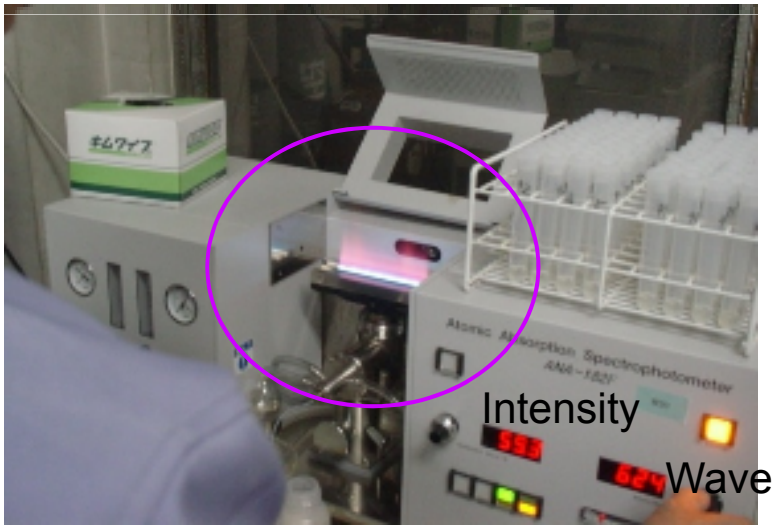


Measurement of Ca Concentration and Isotopic Ratio

Ca Concentration

- Flame photometry

Observation of Light
(Wave length = 622nm)

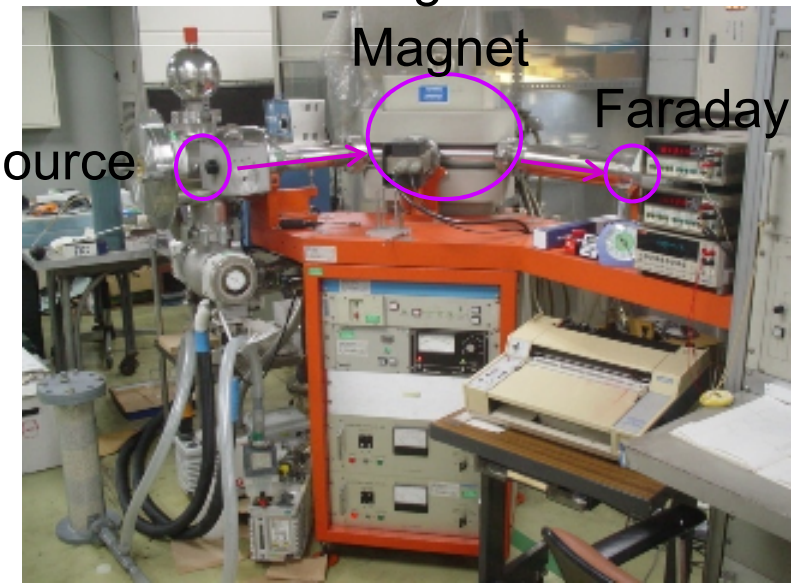


Measurement by using PMT

Isotopic Ratio $^{48}Ca/^{40}Ca$

- Thermal Ionization Mass Spectrometer (TI-MS)

Measurement without Ar gas
… ^{40}Ar is background for ^{40}Ca



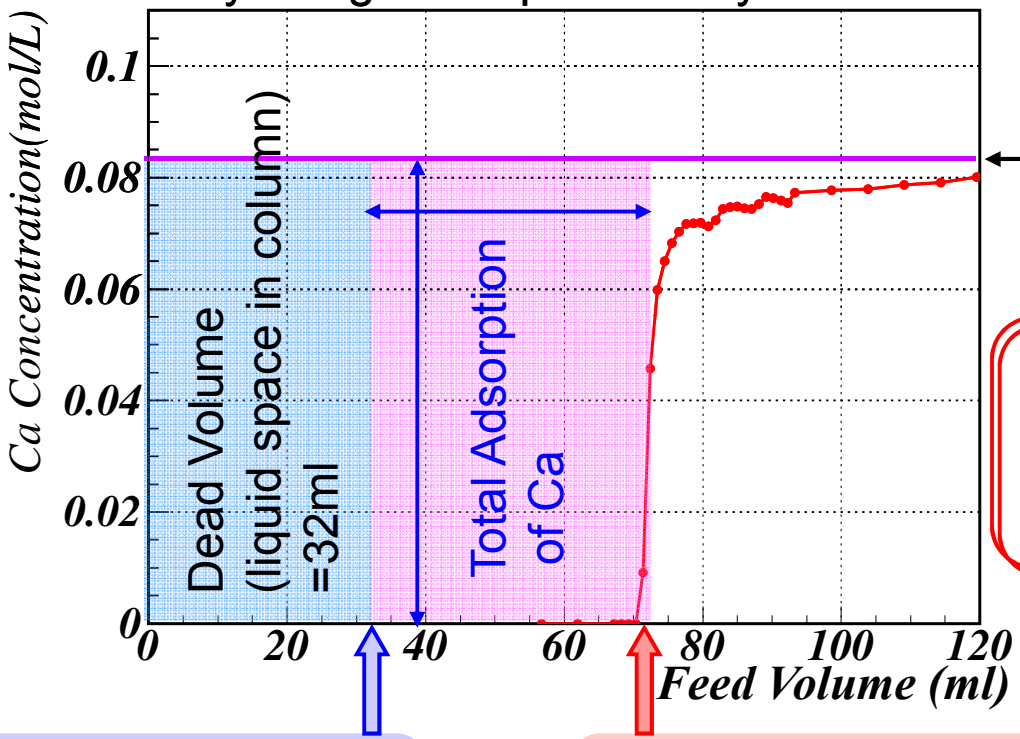
Isotopic ratio of $^{48}Ca/^{40}Ca$
and others (^{42}Ca,^{43}Ca,^{44}Ca)

Calcium Concentration

Result of Migration Length 1m

First Test:Measurement of Ca concentration

by using flame photometry



Ca concentration
of feed solution (~0.1mol/l)

Ca Adsorption by Crown-ether

Ca in 40ml solution is captured.
=Adsorption
by 1/3 of all crown-ether rings

If not adsorbed,
Ca appears
at the point(32ml)

but

In this measurement,
Ca appeared
at this point(72ml)

Isotopic Ratio of Ca is . . . ?

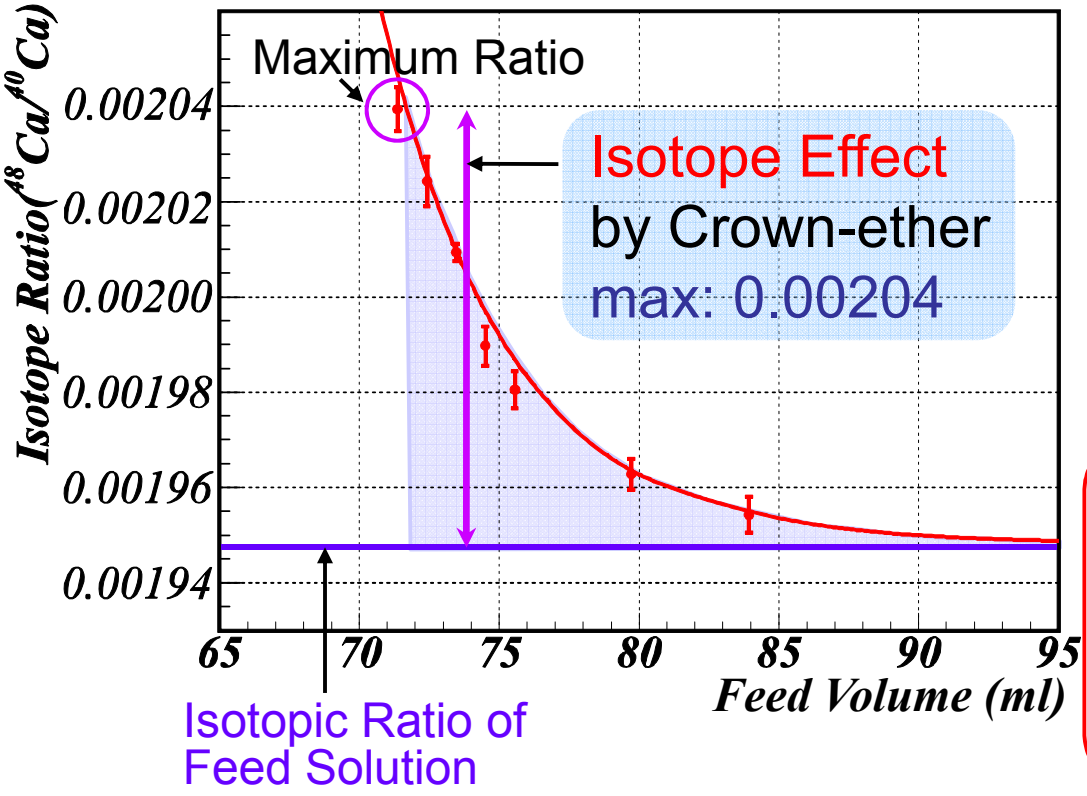
Isotopic Ratio $^{48}Ca/^{40}Ca$

Result of Migration Length 1m

First Test:Measurement of Isotopic Ratio

- by using TIMS(Thermal Ionization Mass Spectrometer)

Isotopic Ratio

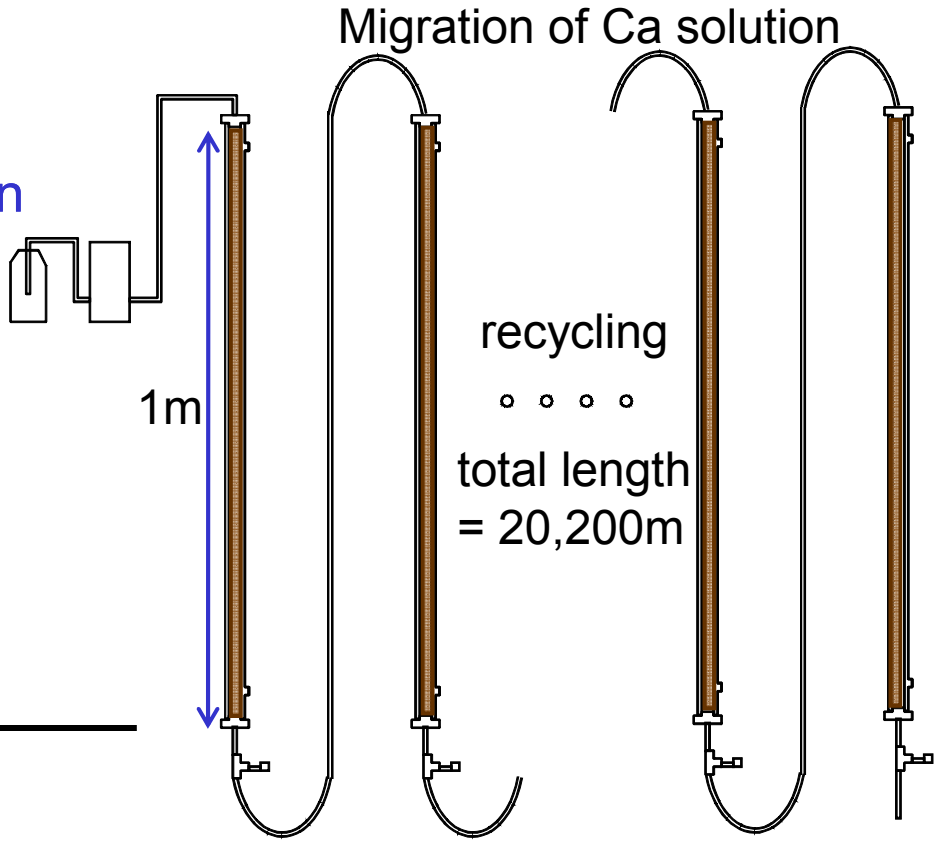


^{48}Ca Enrichment

- It is certain that
  ^{48}Ca is enriched in sol. phase
  by crown-ether resin
- Max Ratio($^{48}Ca/^{40}Ca$):0.00204
  (4.6%up)

Further Enrichment

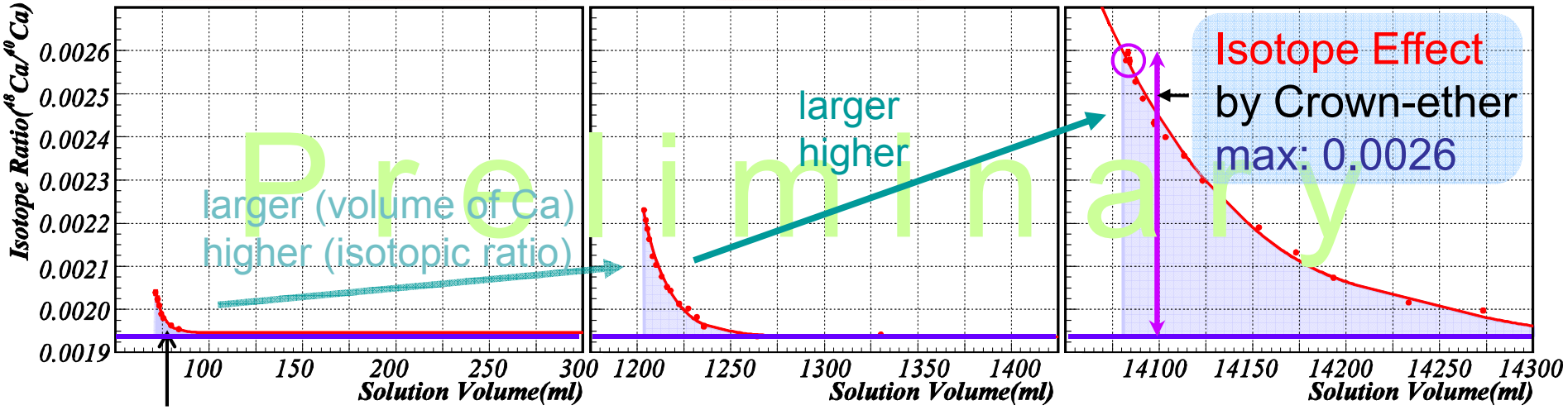
- Further Enrichment
  - First Test
    - 1m glass column was applied.
    - Migration Time(length) = ~7hours(1m)
  - Next = long migration test
    - 10 glass columns(10 × 1m) are applied.
    - Recycling of crown-ether resin after rinsing
    - Total Migration Time(length) = ~70hours(20m), ~250hours(200m)



Further Enrichment

Isotope Enrichment with Longer Migration Time(Length)

~7hours
1m migration length
→ longer →
~70hours
20m
→ longer →
~250hours
200m



Amount of Enrichment by Crown Ether

Isotope Effect (Enrichment Effect)

- The longer migration time(length) =
  the larger volume and the higher isotopic ratio
  ~7hours(1m) → ~250hours (200m)
  volume: ×17、isotopic ratio: ×8

Current Rough Estimation

- for 2% ^{48}Ca、200kgCalcium
  - Crown-Ether Resin 30ton : $30M
  - Migration time : 1.5 years
- for improvement
  - Kind of Crown-ether
    - Now:Benzo-18-crown-6-ether
    - Candidate : for example. . .

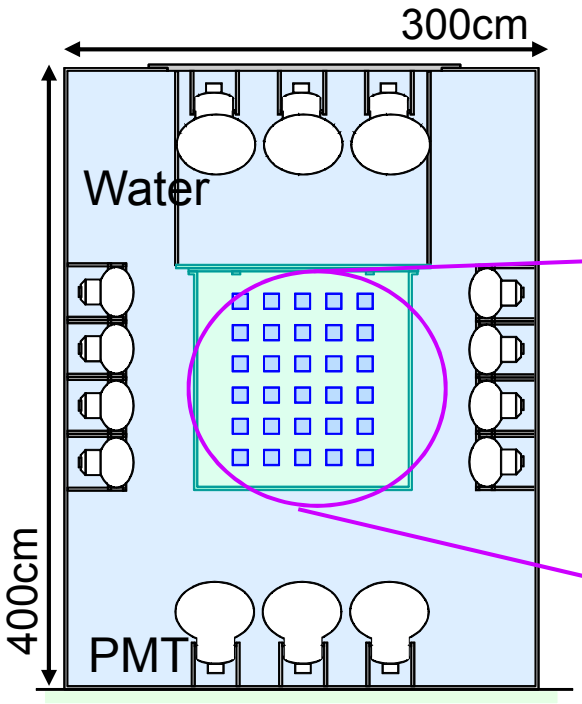
      Dibenzo-18-crown-6-ether → inexpensive (~1/10)
  - Optimization of migration parameter
    - Solvent : (now) HCl → (Candidate) Organic solvent (methanol. . .)
      - Good adsorptive rate
    - Migration speed : (now)0.3ml/min,1ml/min→3ml/min. . .

      time effective

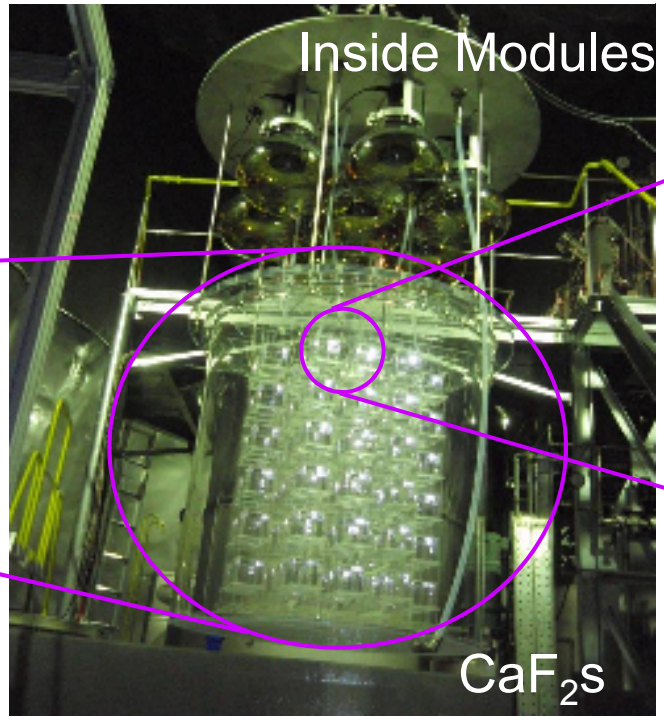
Future:
Detector system for Double Beta Decay

CANDLES System

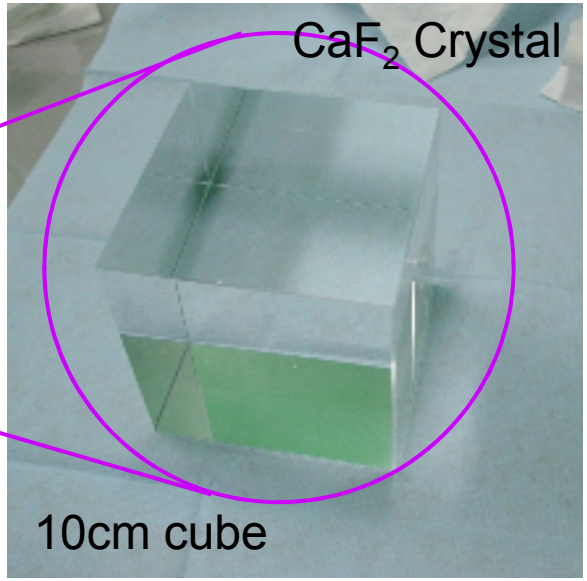
CaF_2(pure) Scintillators
Liquid Scintillator



Schematic View of CANDLES III
at Kamioka Obs.



Main detector CaF_2 will be replaced …



. . . with $^{48}CaF_2$ (~2%) !

Summary

- ^{48}Ca Enrichment by using Crown-ether
  - to apply Crown-ether resin
- Isotope Effect
  - Crown-ether adsorbed Ca ion
  - ^{48}Ca is enriched in solution phase.
  - 4.6%(max) up of ^{48}Ca abundance with ~7hours Exp.
  - Isotopic ratio of ^{48}Ca increased with migration length
  - Ca volume: ×17
Maximum isotopic ratio: ×8 } with ~250 hours Exp.
- In future
  - Study for a higher isotopic ratio, a larger amount of ^{48}Ca with cost and time effective parameters