PANIC 14
Particles and Nuclei
International Conference

Future opportunities with Germanium detectors at the Jinping Underground Laboratory

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On behalf of the GeDet Collaboration @ MPI Munich

Outline

→ **Introduction**
- rare events searches
- low background facilities

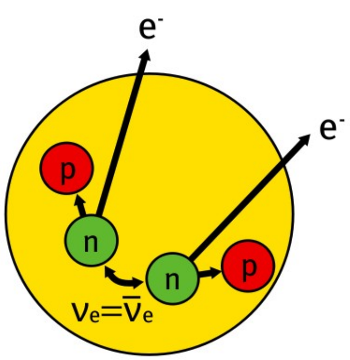
→ **China Jinping Underground Laboratory (CJPL)**
- CJPL1 facility
- running experiments
- possible 1 Ton facility
- CJPL2 facility

→ **Detector Development**
- first results with alpha scan

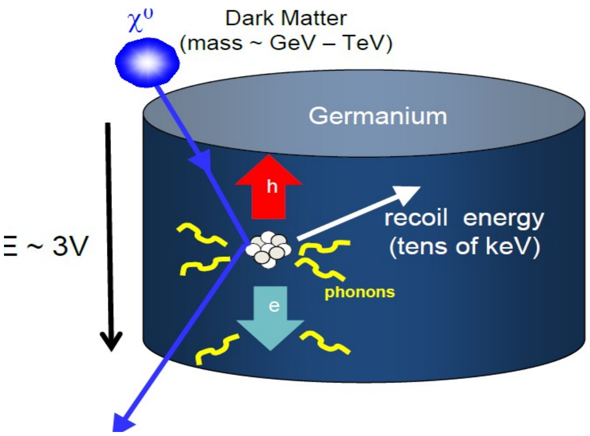
→ **Summary and Outlook**

Two interesting sectors in physics are Neutrinos and Dark Matter

Using Germanium we can learn something about both:



- **^{76}Ge can decay via double beta decay**
  - 0νββ decay could give us informations about:
    - Lepton Number Violation
    - Neutrinos nature



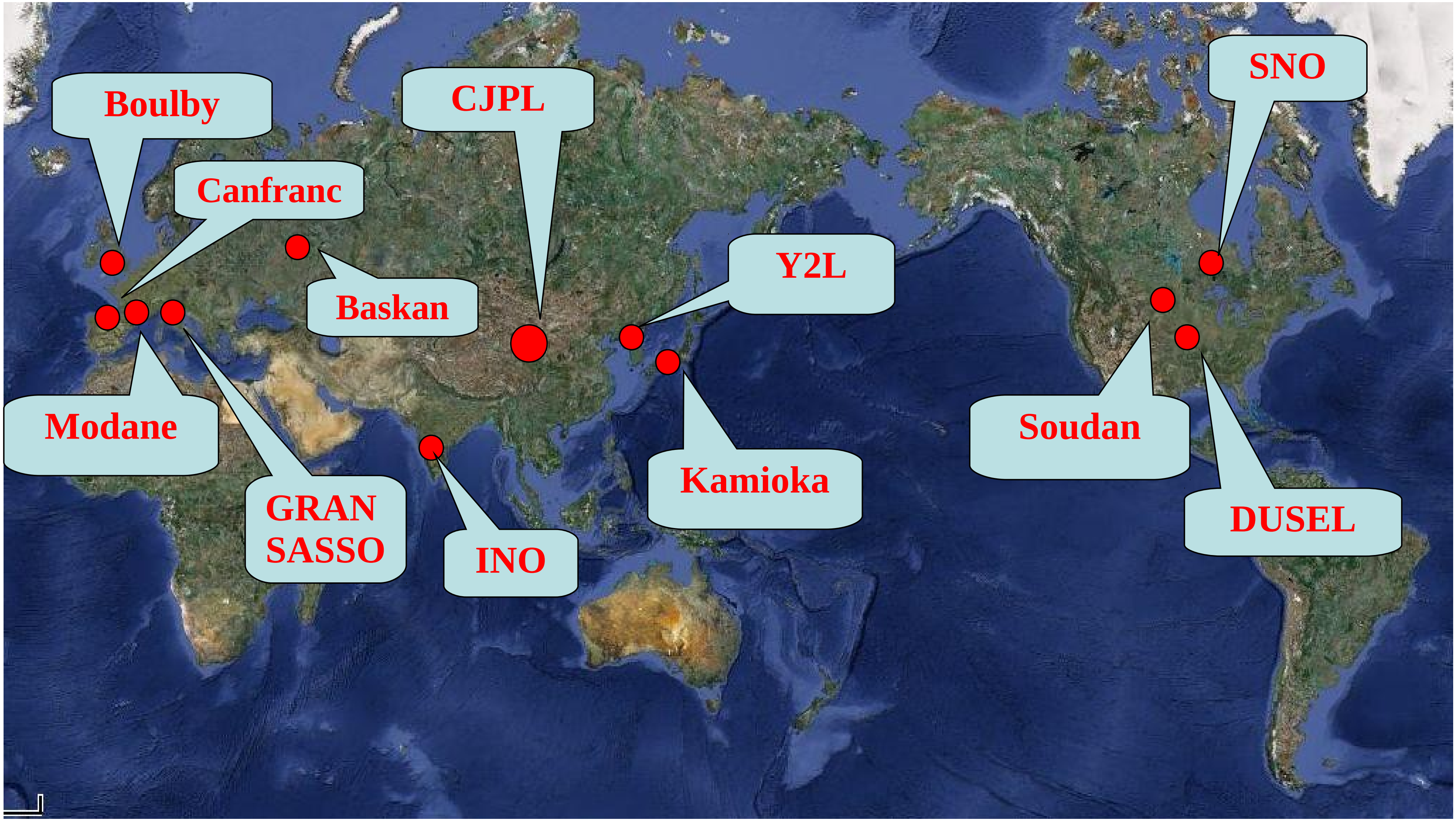
- **Germanium can be used to probe WIMP interactions with matter**
  - from the cross section → mass of the WIMP
  - understand origin of DM

CHALLENGES:

- very good energy resolution at 2 MeV needed for 0νββ
- very low energy threshold needed for DM
- huge detector (=> 1 Ton detector array)
- **low background (=> underground lab)**

Introduction: low background laboratories (I)

Underground laboratories all over the world



Deutsch-Chinesische-Kooperationsgruppe

Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)

SHANGHAI JIAO TONG UNIVERSITY

TSINGHUA UNIVERSITY

EBERHARD KARLS UNIVERSITÄT TÜBINGEN

Deutsch-Chinesische-Kooperationsgruppe

Development of High Purity Germanium Detector Techniques for Applications in Fundamental Research

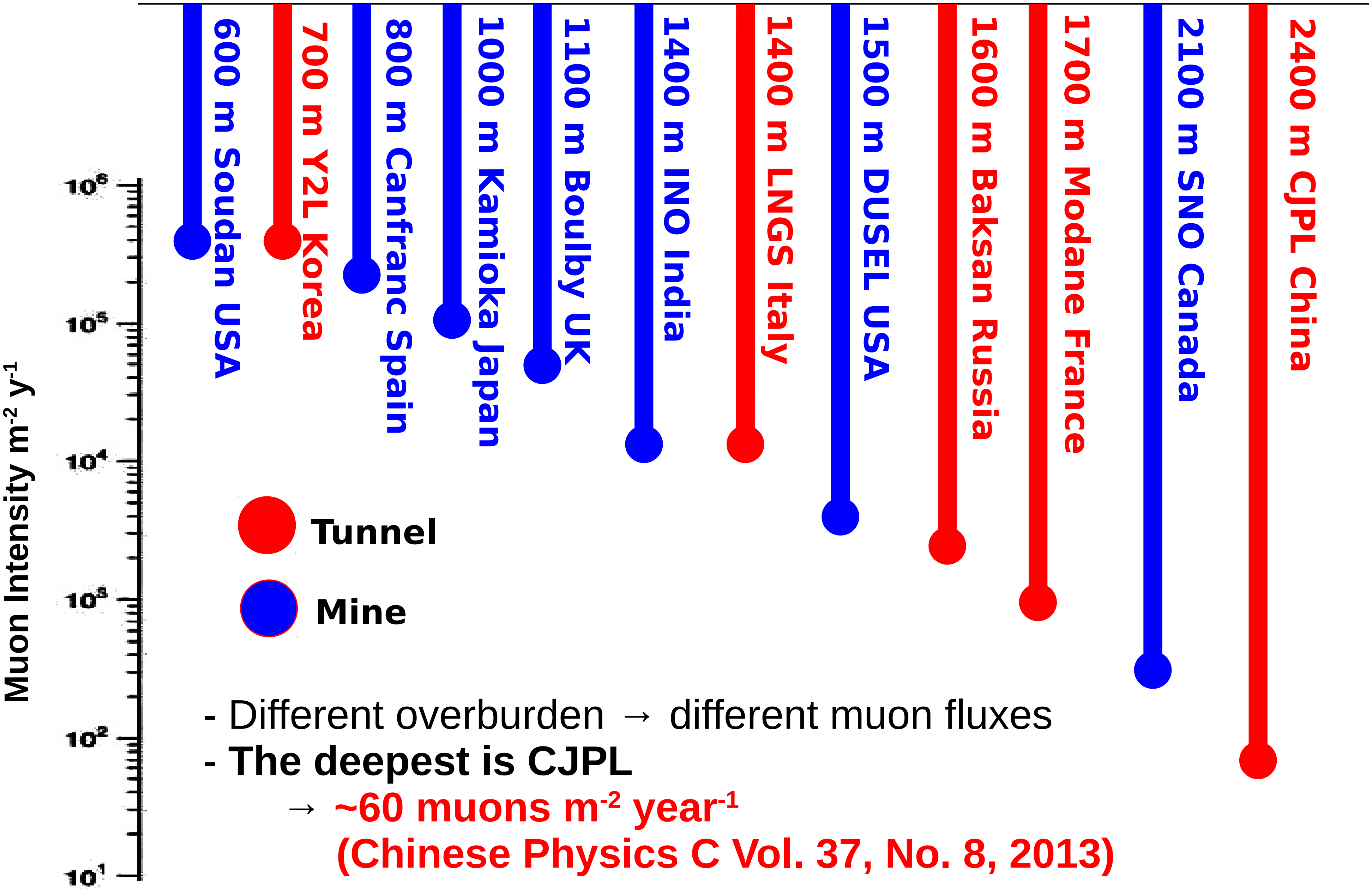
Finanziell unterstützt durch: Chinesisch-Deutsches Zentrum für Wissenschaftsförderung Peking, China

中德合作研究小组

应用于基础研究的高纯锗探测器技术研发

资助者:中德科学中心 / 中国 北京

Introduction: low background laboratories (II)



- Different overburden → different muon fluxes
- **The deepest is CJPL**

→ **~60 muons m^{-2} $year^{-1}$**
(Chinese Physics C Vol. 37, No. 8, 2013)

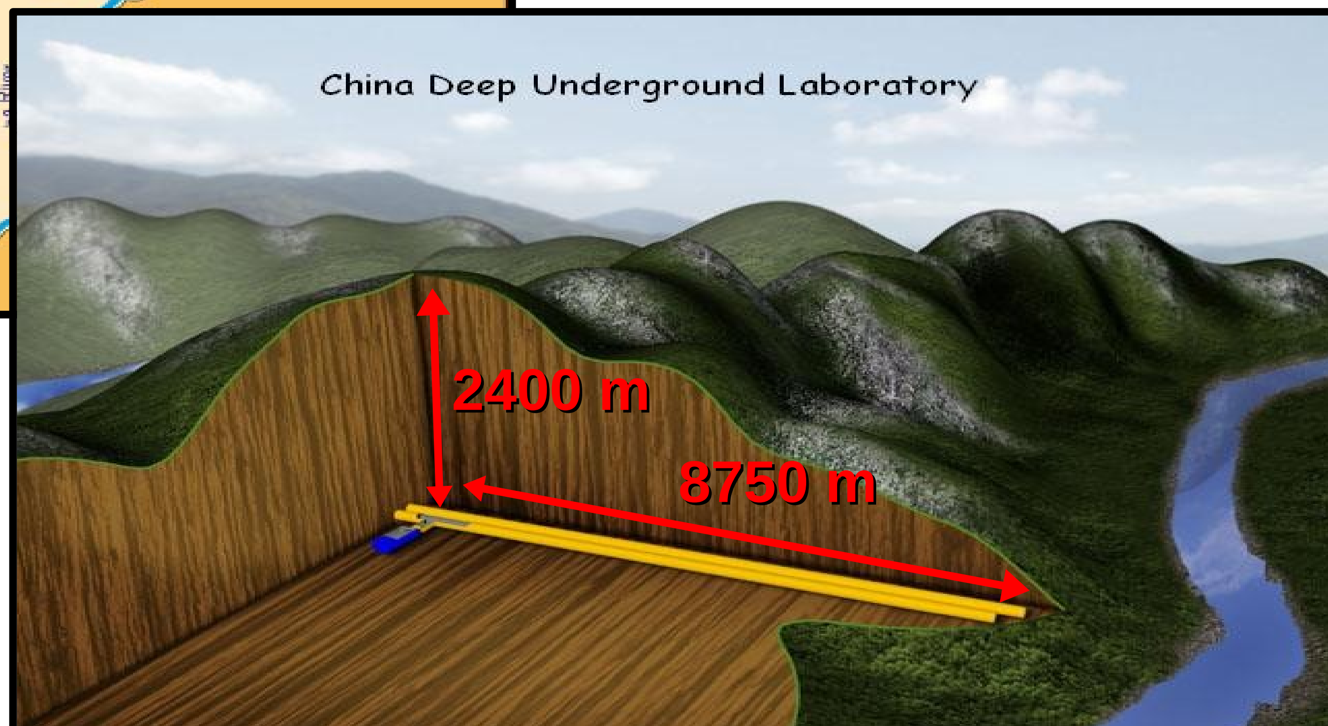
China JinPing Laboratory 1: facility (I)

- **Sichuan Province**, South West China

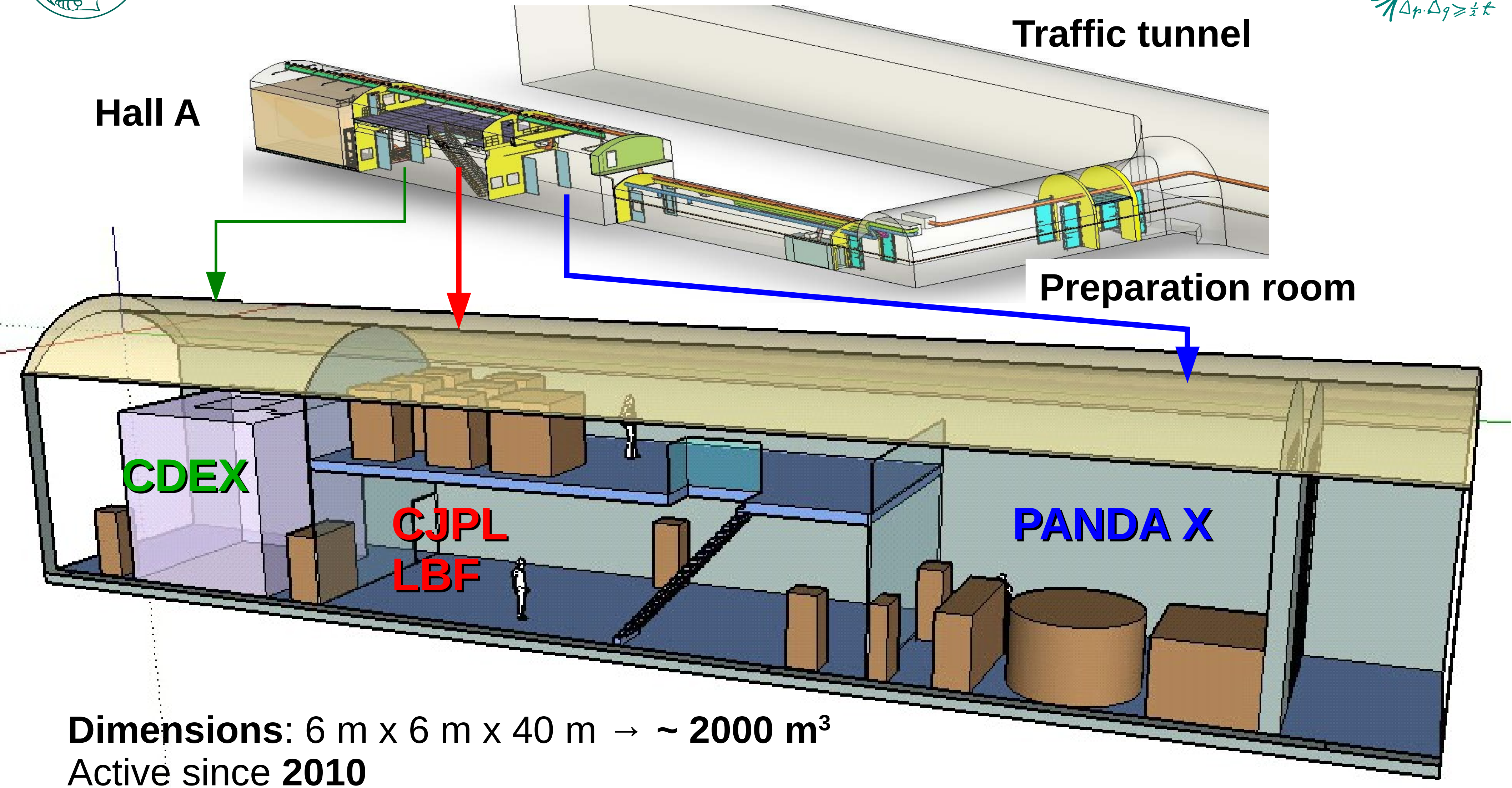
- **hydropower plants** at each side of the mountain

- **two parallel support tunnels**
    - total length: 17,5 km
    - x-section: 6 m x 6 m
    - overburden: 2400 m

DEEPEST UNDERGROUND LABORATORY WITH HORIZONTAL ACCESS



CJPL1: facility (II)



Dimensions: 6 m x 6 m x 40 m → **~ 2000 m³**

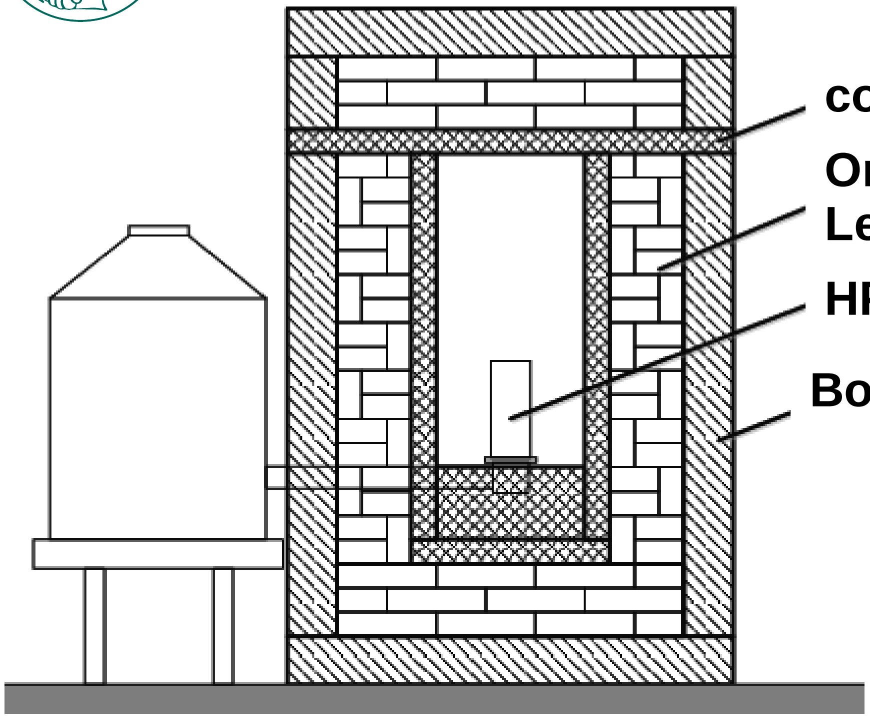
Active since **2010**

CDEX: China Dark Matter Experiment

CJPL LBF: Background monitoring

PANDA X: Xenon based Dark matter Experiment

Running experiments: CJPL-LBF

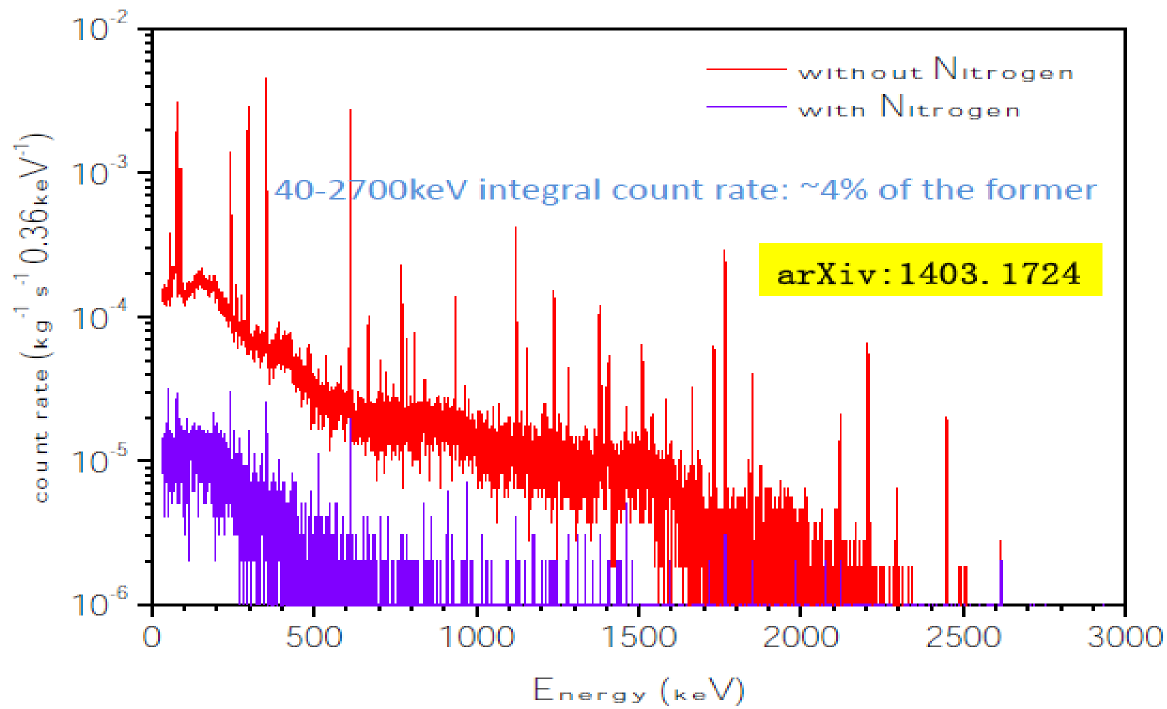


GeTHU 1:

Low Background gamma ray spectrometer:

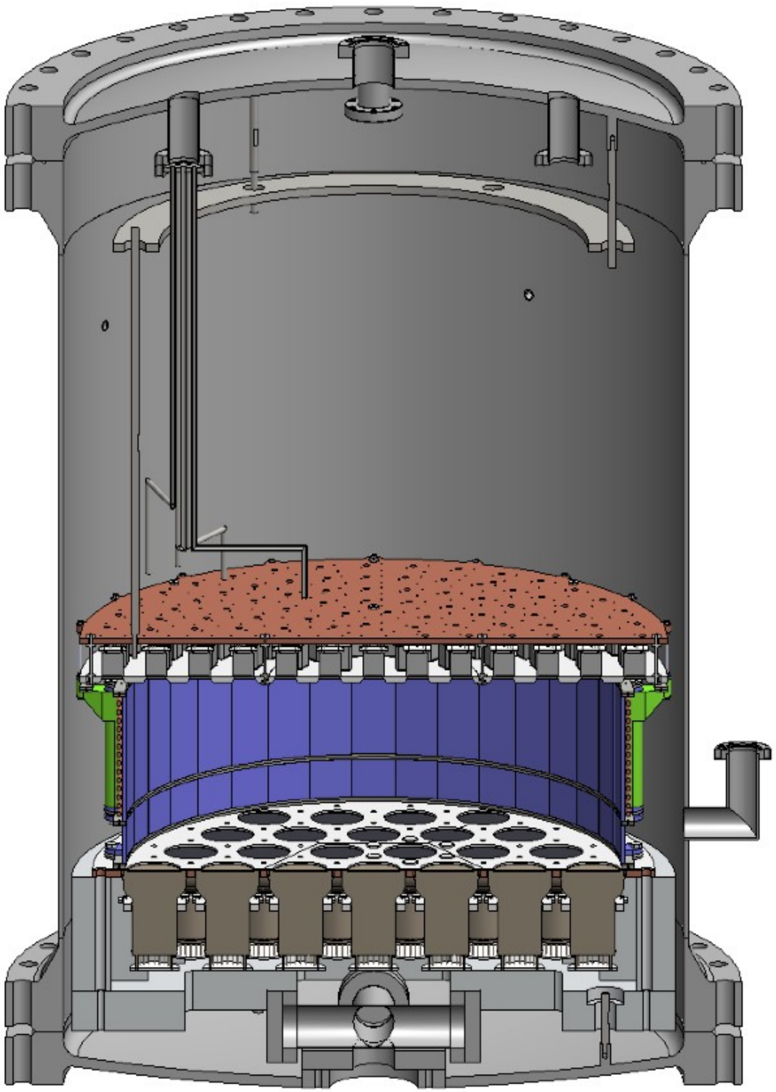
- **measurements of environmental samples**
- **material selection**

- **12 days** of background measurement
- clear effect of the **nitrogen flushing**
  → reduce ^{222}Rn concentration



Running experiments: PANDA X

Panda X stage Ia:
125 kg target/30 kg fiducial



Direct DM search:
Liquid Xenon equipped with PMTs

Passive multilayer shield

PANDA X is SCALABLE:
- stage Ia: 30 kg fiducial volume
- stage Ib: 300 kg fiducial volume
- stage II: 1 Ton fiducial volume

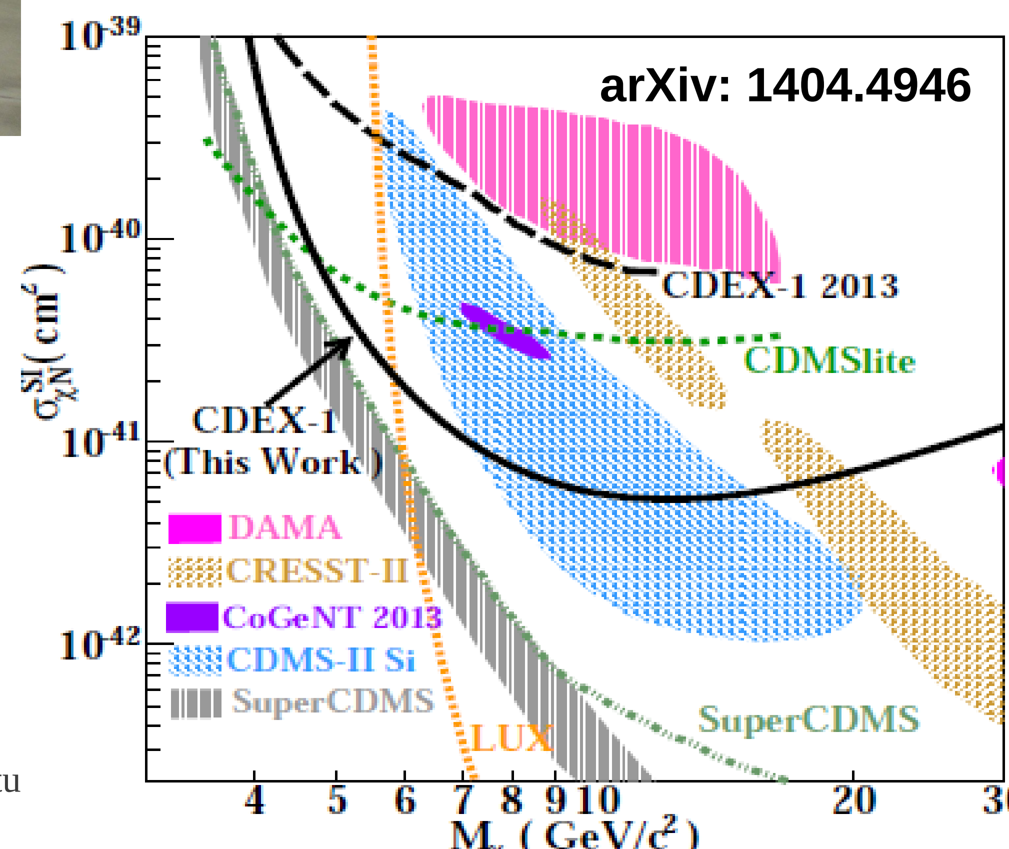
SCIENCE DATA TAKING since March 2014

Running experiments: China Dark Matter EXperiment

CDEX-I is running in CJPL

Two High Purity Germanium Detectors

- **20 g Ul**tra **L**ow **E**nergy threshold **Ge**rmanium detector
- **1 kg p**-type **P**oint **C**ontact **Ge**rmanium detector



- Latest results published in 2014
- **CDEX-1 still taking data**

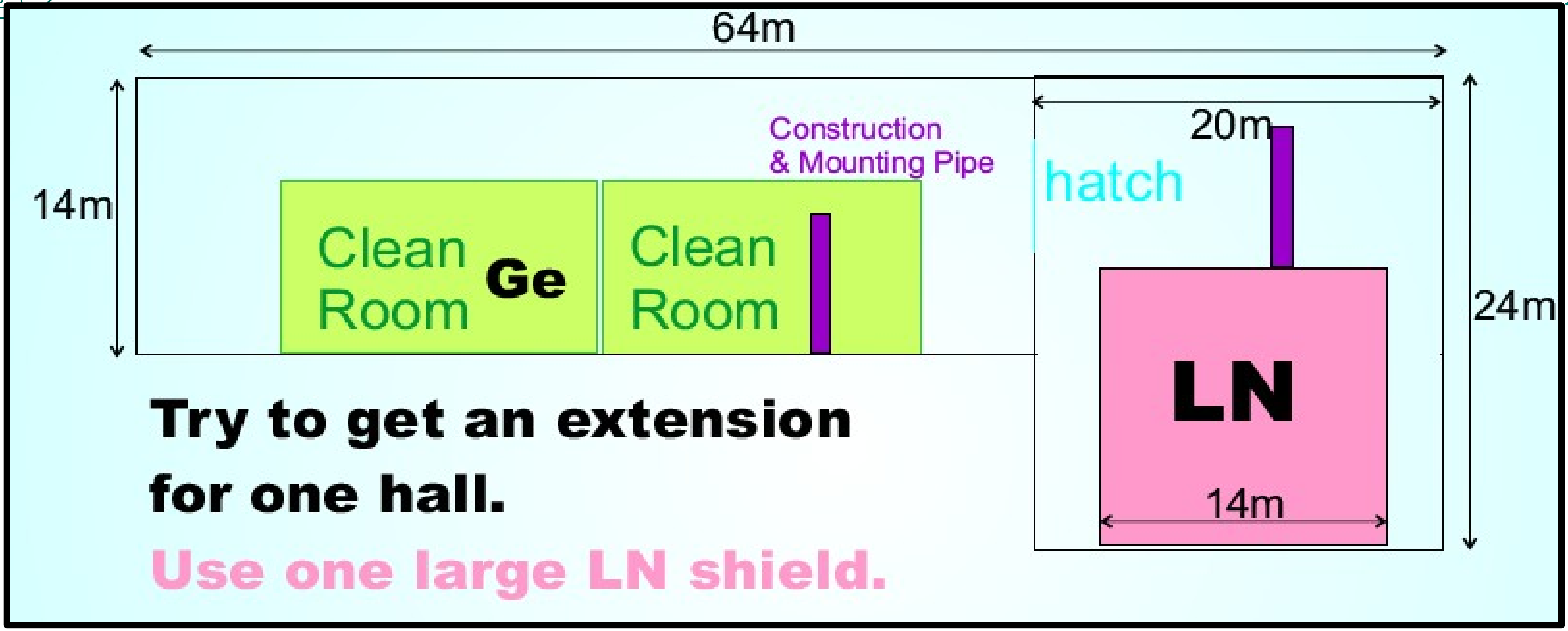
CDEX-10:

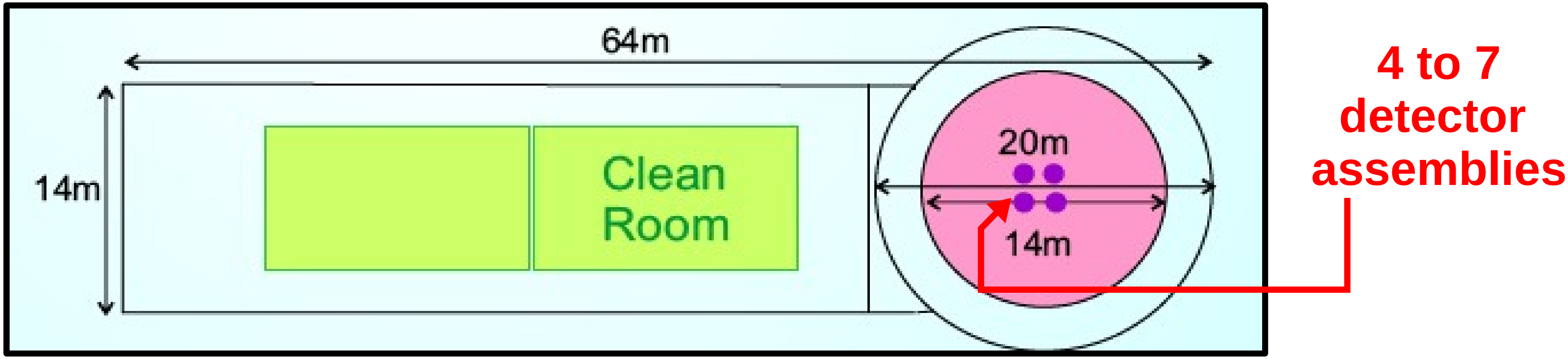
- simulation studies on the bkg
- shielding system
- detector fabrication

CDEX-1Ton:

- towards a multi-purpose experiment

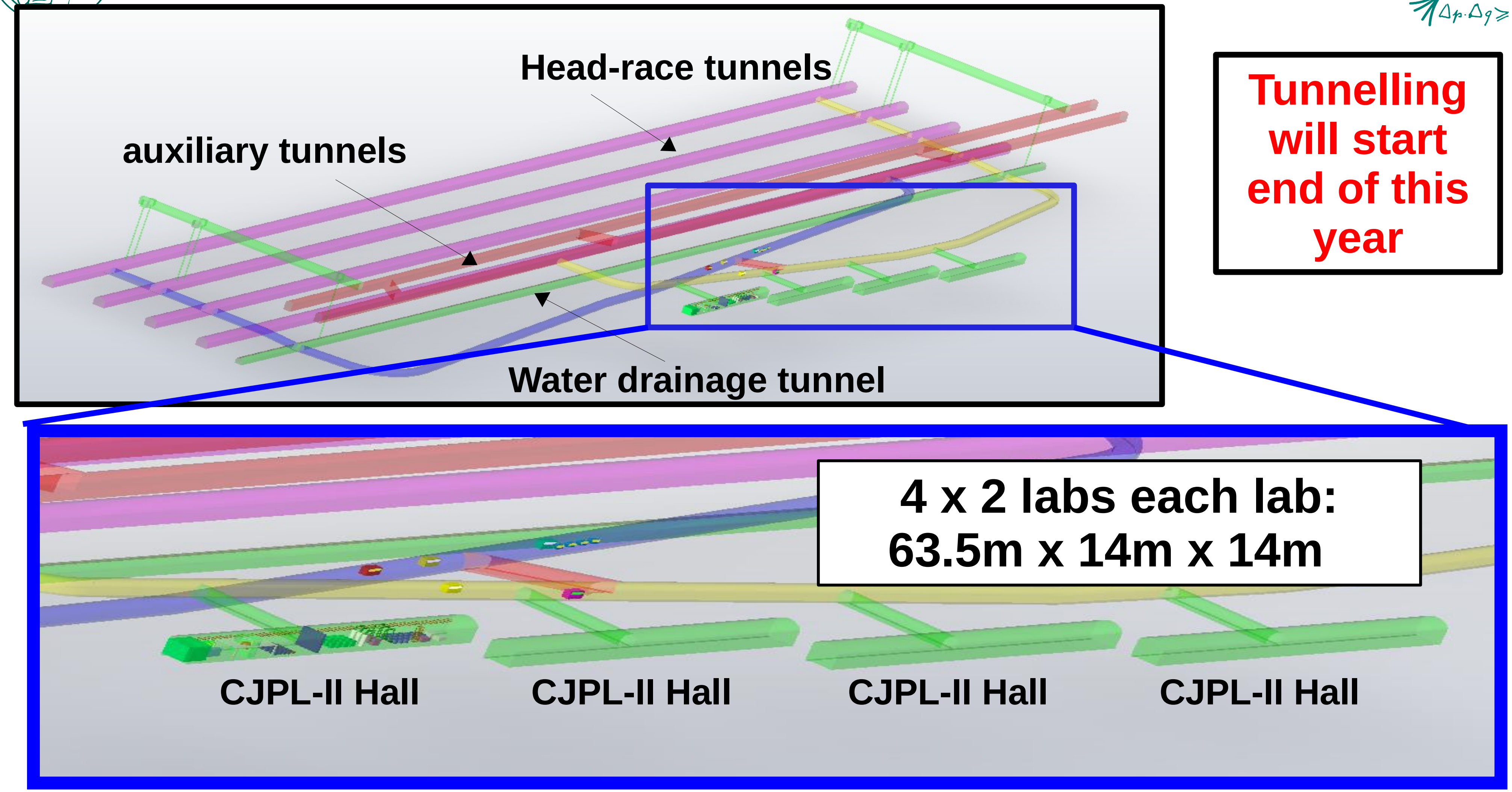
1 Ton facility: possible infrastructure





Courtesy of Dr. I. Abt

CJPL 2

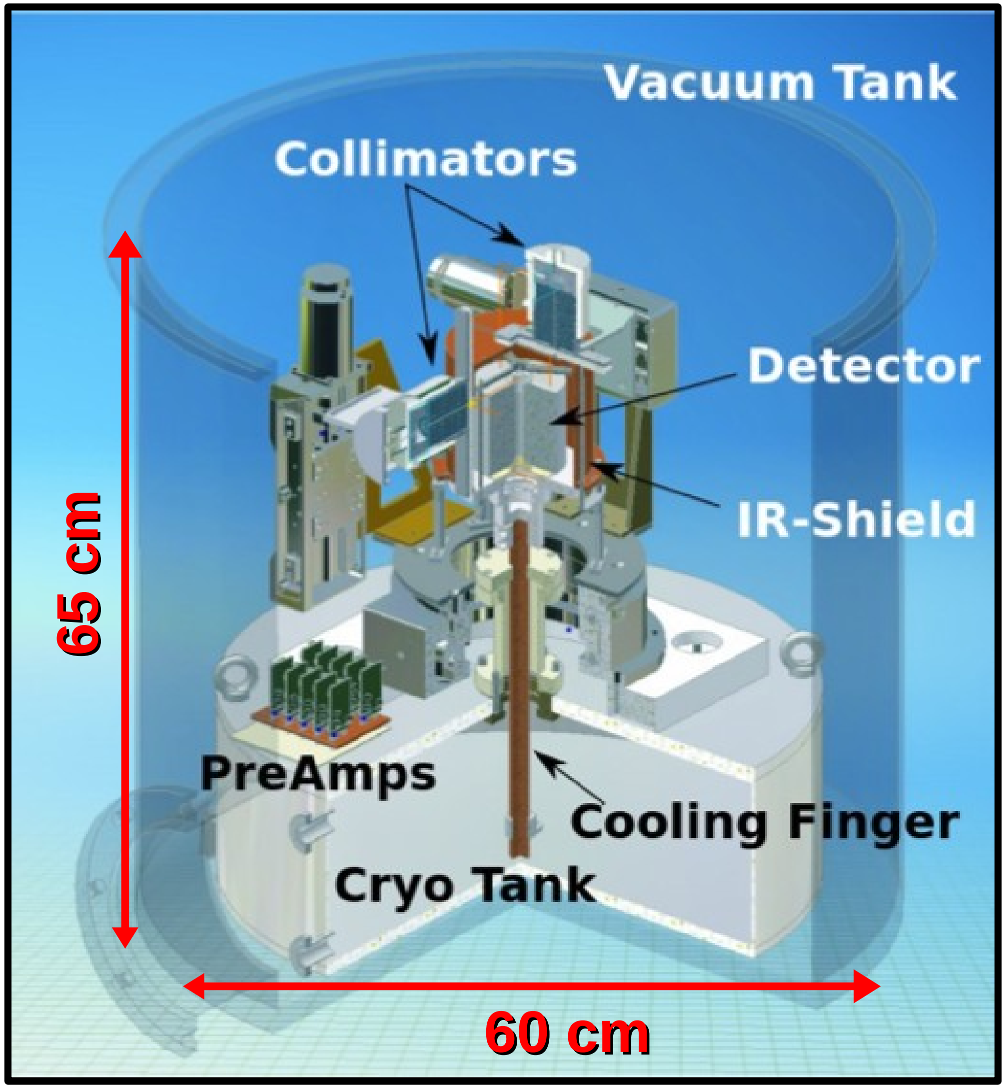


Tunnelling will start end of this year

- physics experiments: 1 Ton facilities
- electro-formed copper production and machinery
- germanium detectors production

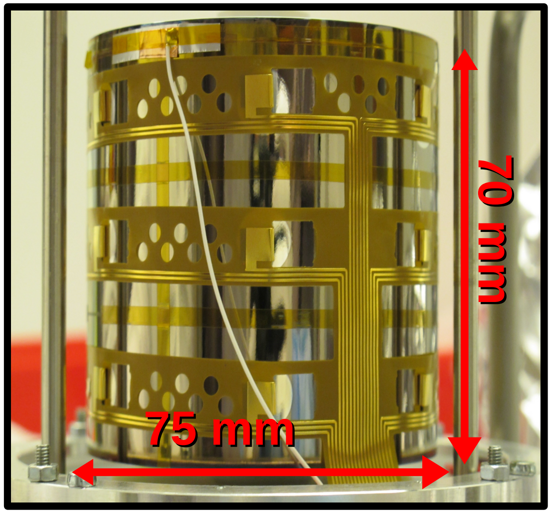
Detector development studies (I)

muon induced bkg is so reduced → other bkg sources become important
→ alpha background => characterization of detector response to alphas



GALATEA test facility:

- vacuum chamber
    - low penetrating sources
- cryo tank to cool down the detector
- 3 motors to move 2 collimators in 3D
    - alpha source placed in the top one
- electronics inside

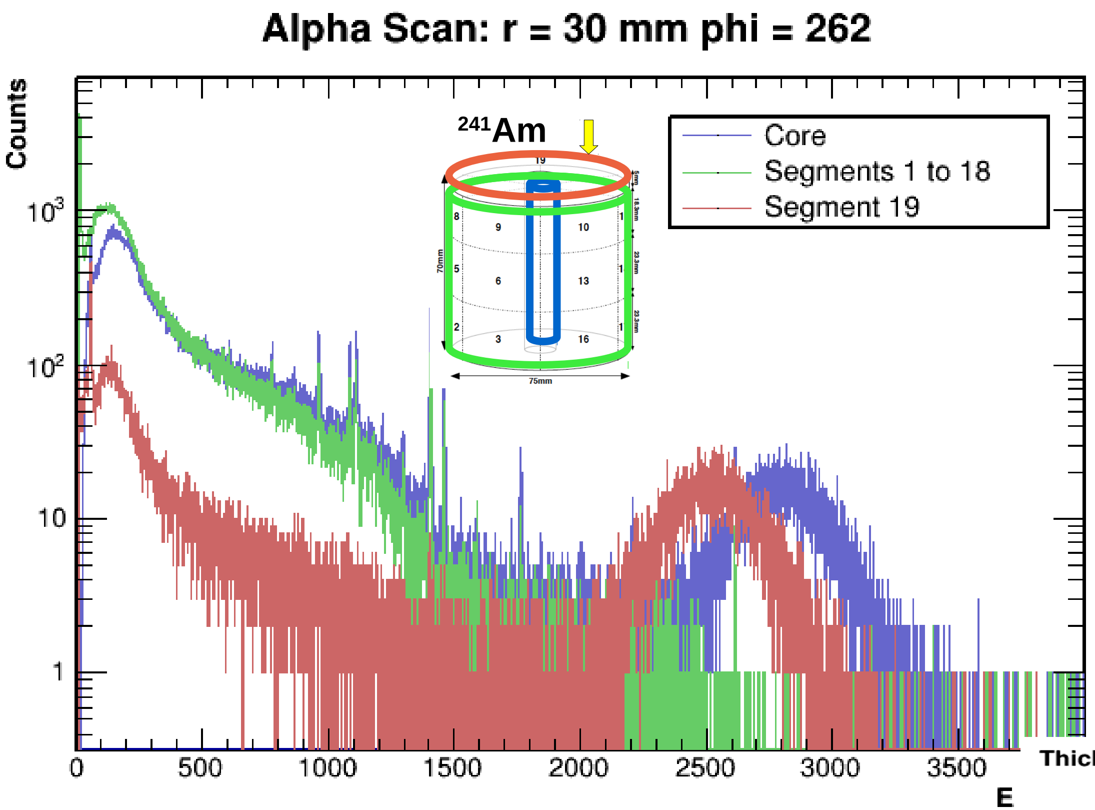


Passivation layer on top

↓

Characterization of the dead layer

Detector development studies (II)

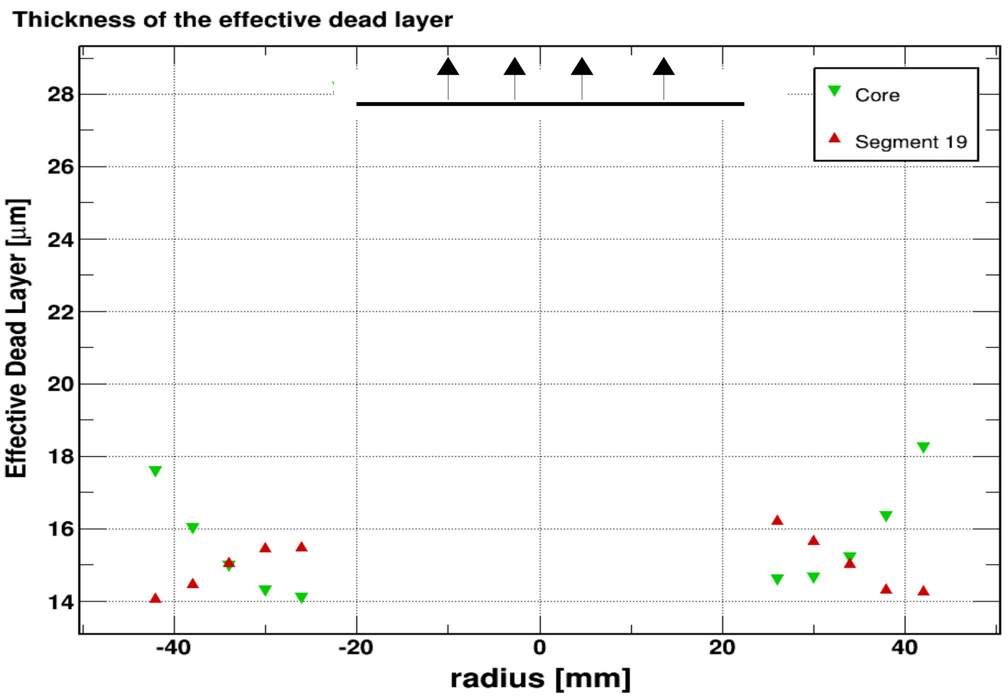


Energy spectra:

- gamma lines
- alpha bump on the top segment
  - different position of the bump ← charge trapping
- interesting signature of bkg events

Effective dead layer:

- top surface scan along the radius
- effective dead layer different for different charge carriers



Summary and Outlook

→ Conclusions

- CJPL I is the deepest existing underground laboratory with 2400 m of overburden

- Two Direct detection Dark Matter experiments are running at the moment

- CJPL II will consist of 8 experimental hall for a total volume of 96000 m^3

- CJPL can be a candidate to host a 1 Ton multi-purpose Germanium based experiment

- Detector development studies are performed at the MPI for Physics in Munich

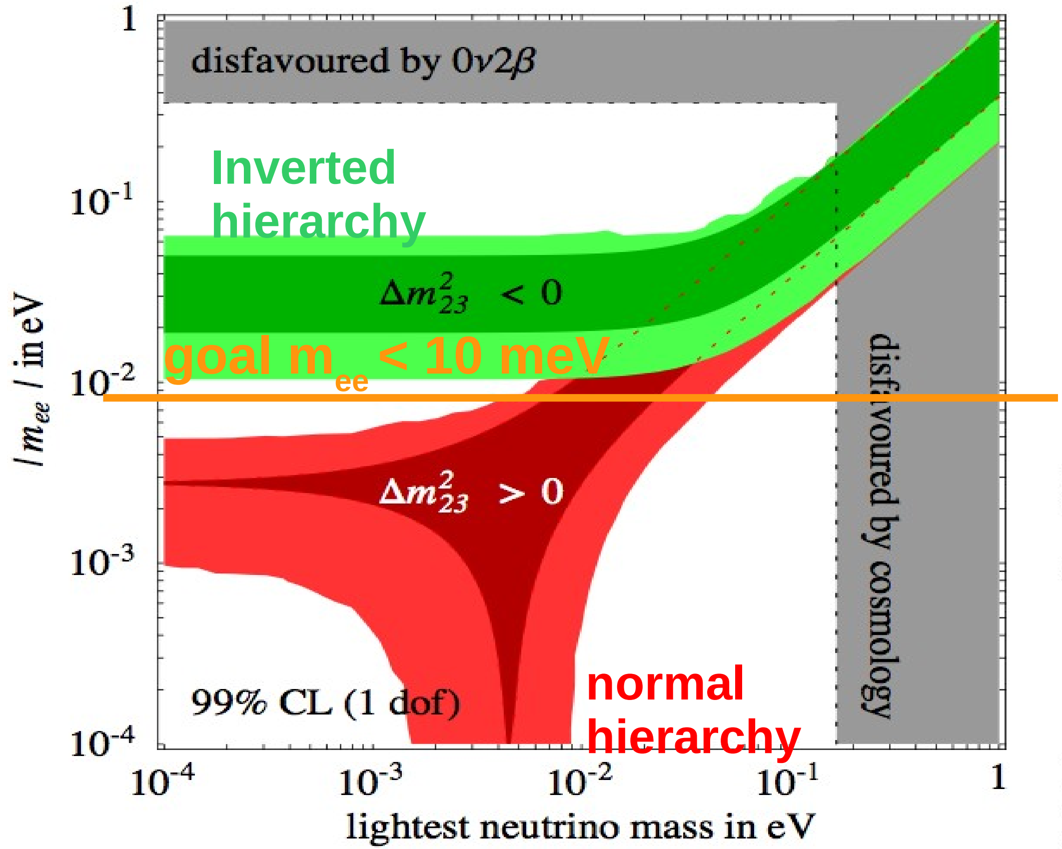
→ Next steps

- identify possible detector techniques to combine 0nubb decay and DM searches

- complete the feasibility study for a 1 Ton Germanium facility

BACKUP SLIDES

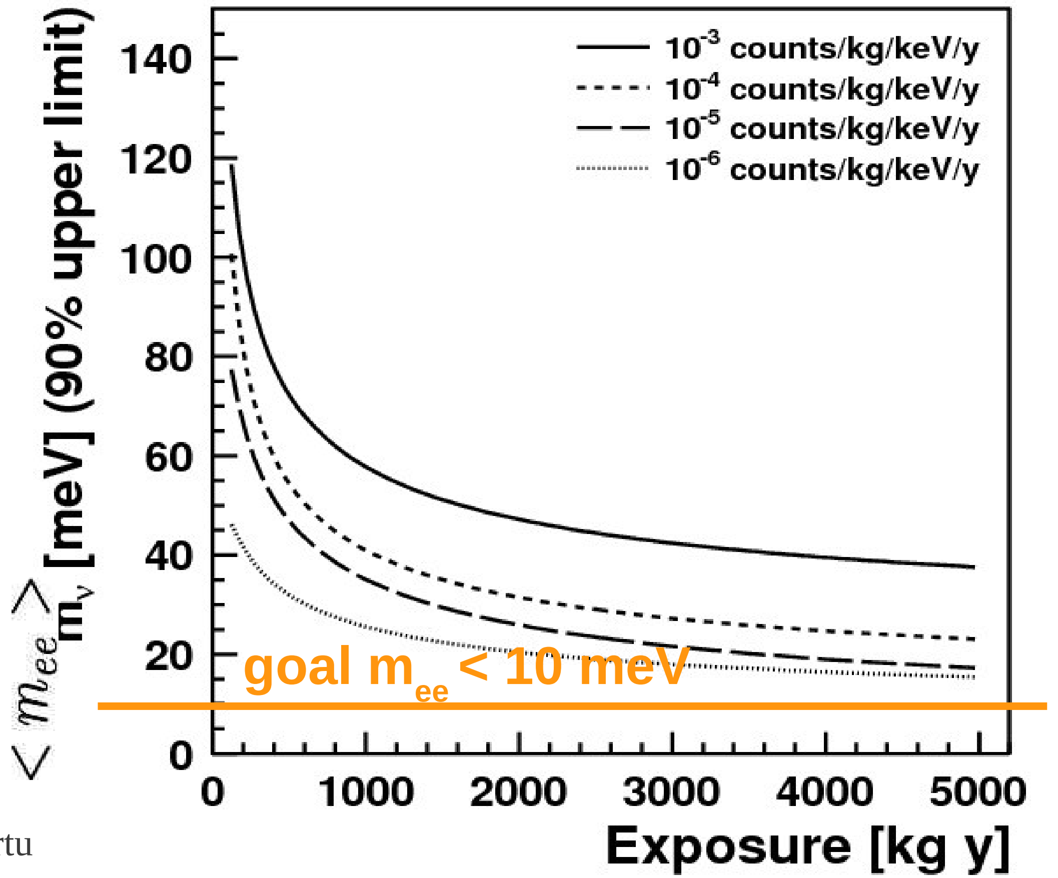
Introduction: Background requirements



0νββ decay can also tell us:

- something on the **hierarchy**
- something on the **absolute mass scale**

BUT only if we have a really low background!!!



cosmic rays create background

⬇

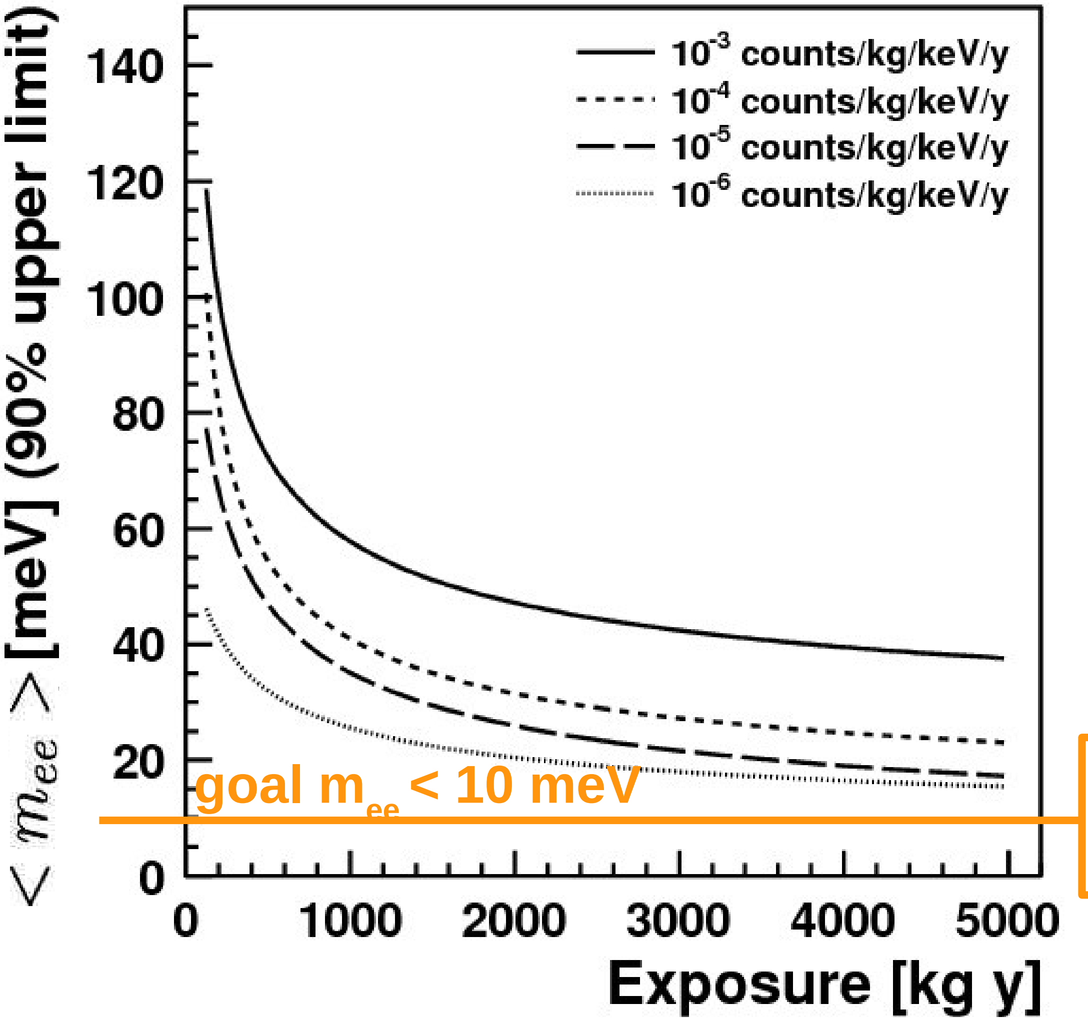
DEEP UNDERGROUND LABORATORIES

Next generation experiments

- How can we reach that?

$$T_{\frac{1}{2}}^{0\nu\beta\beta} \propto \sqrt{\frac{M \cdot T}{B \cdot \Delta E}} \quad \Rightarrow \quad \langle m_{ee} \rangle^2 \propto \sqrt{\frac{B \cdot \Delta E}{M \cdot T}}$$

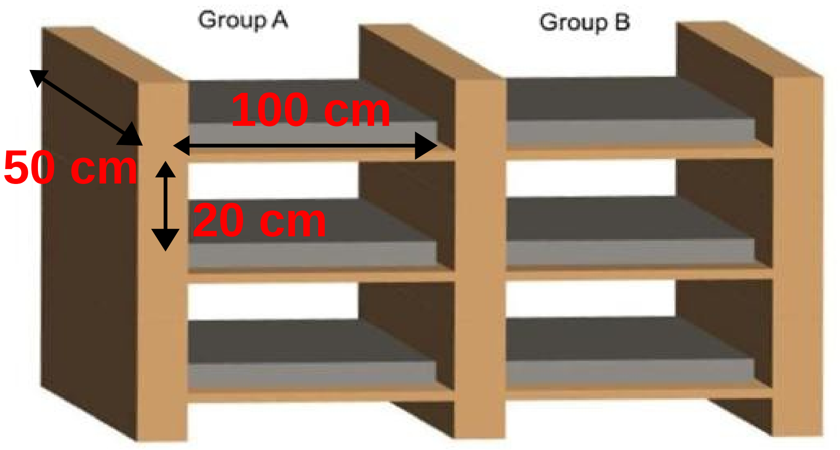
Less is better!!

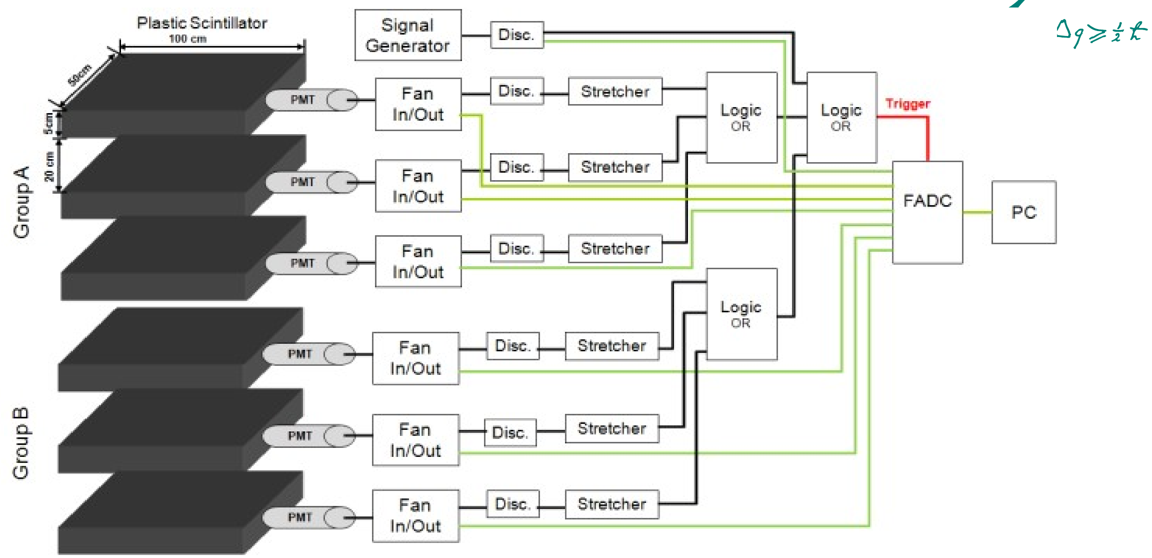


- **bigger exposure**:
  - bigger mass → **1 ton**
- **lower Background index B**
  - better **shielding**
  - better **b/s discrimination**
- **smaller search window**
  - better **energy resolution**

Can it be reached with one Ton of Germanium?

CJPL1: muon flux measurement





Chinese Physics C Vol. 37, No. 8 (2013)

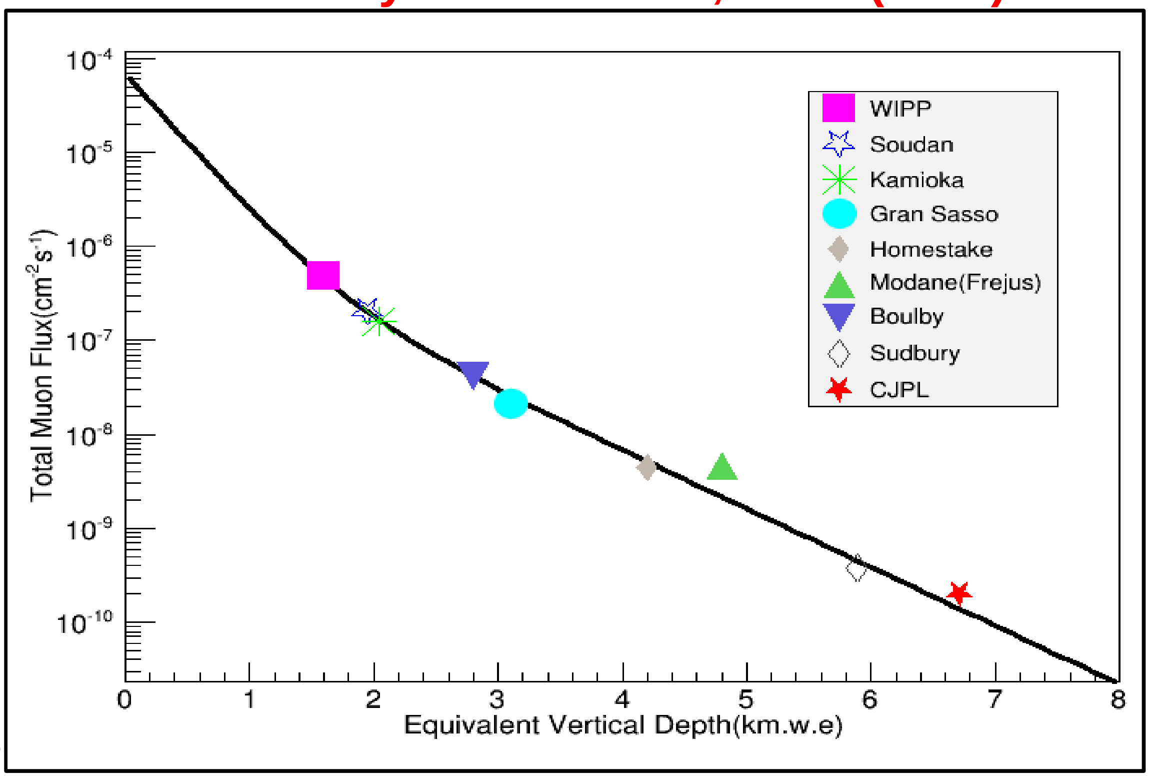
- Telescope system with 6 **plastic scintillators**

- the system was first **tested in a ground laboratory**

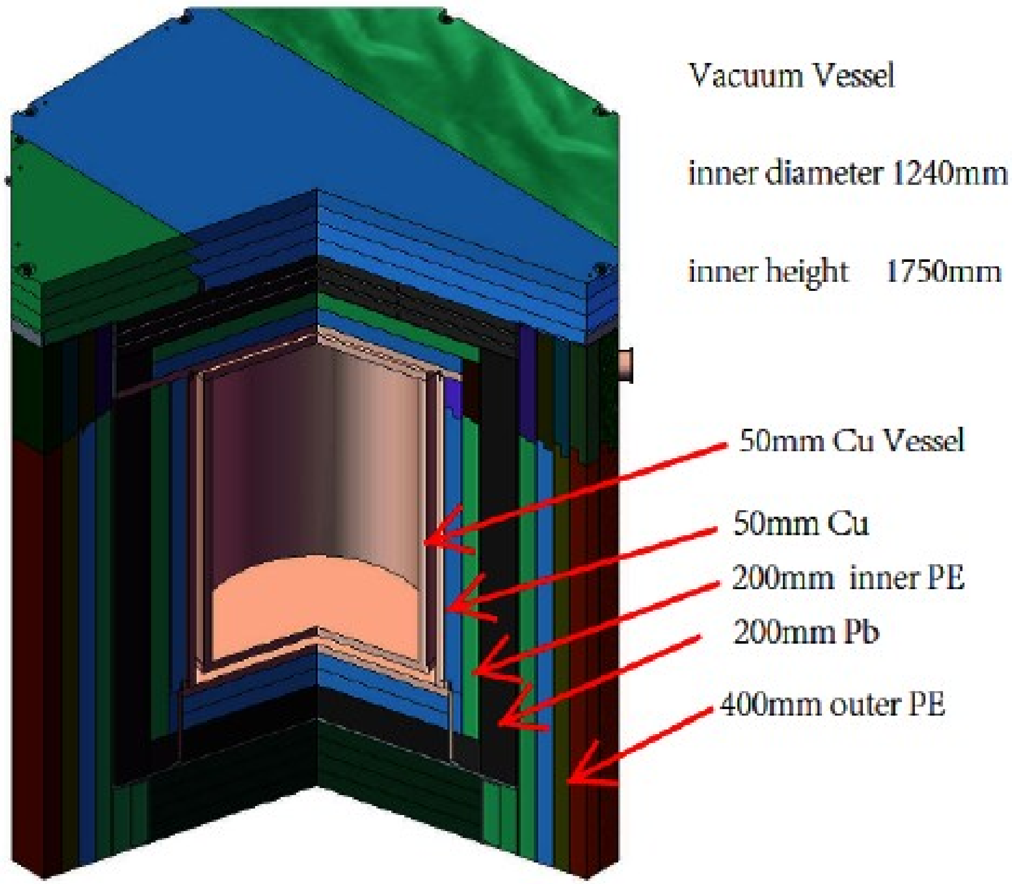
- Data taking: from **November 2010 to December 2011**

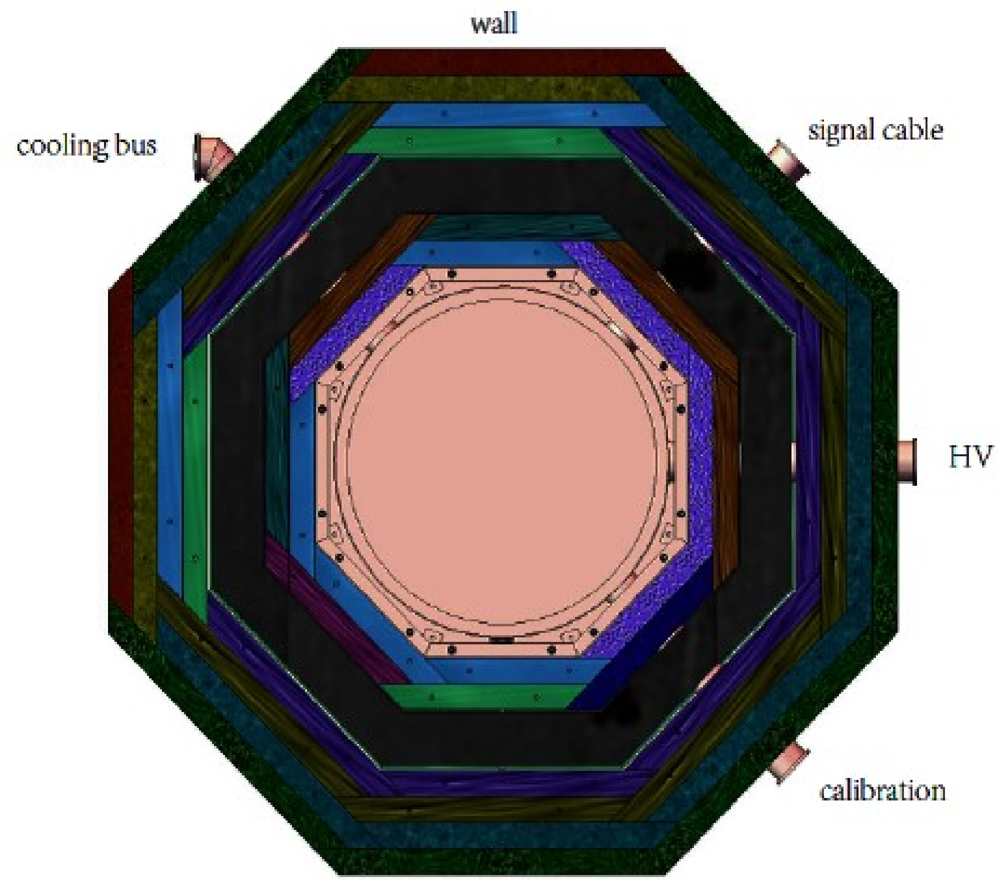
- **Pulse Shape and triple coincidence selections**

$$(2.0\pm0.4)\times10^{-10}\ /(\mathrm{cm}^2\ \mathrm{s})$$



PANDA X: multilayer passive shield



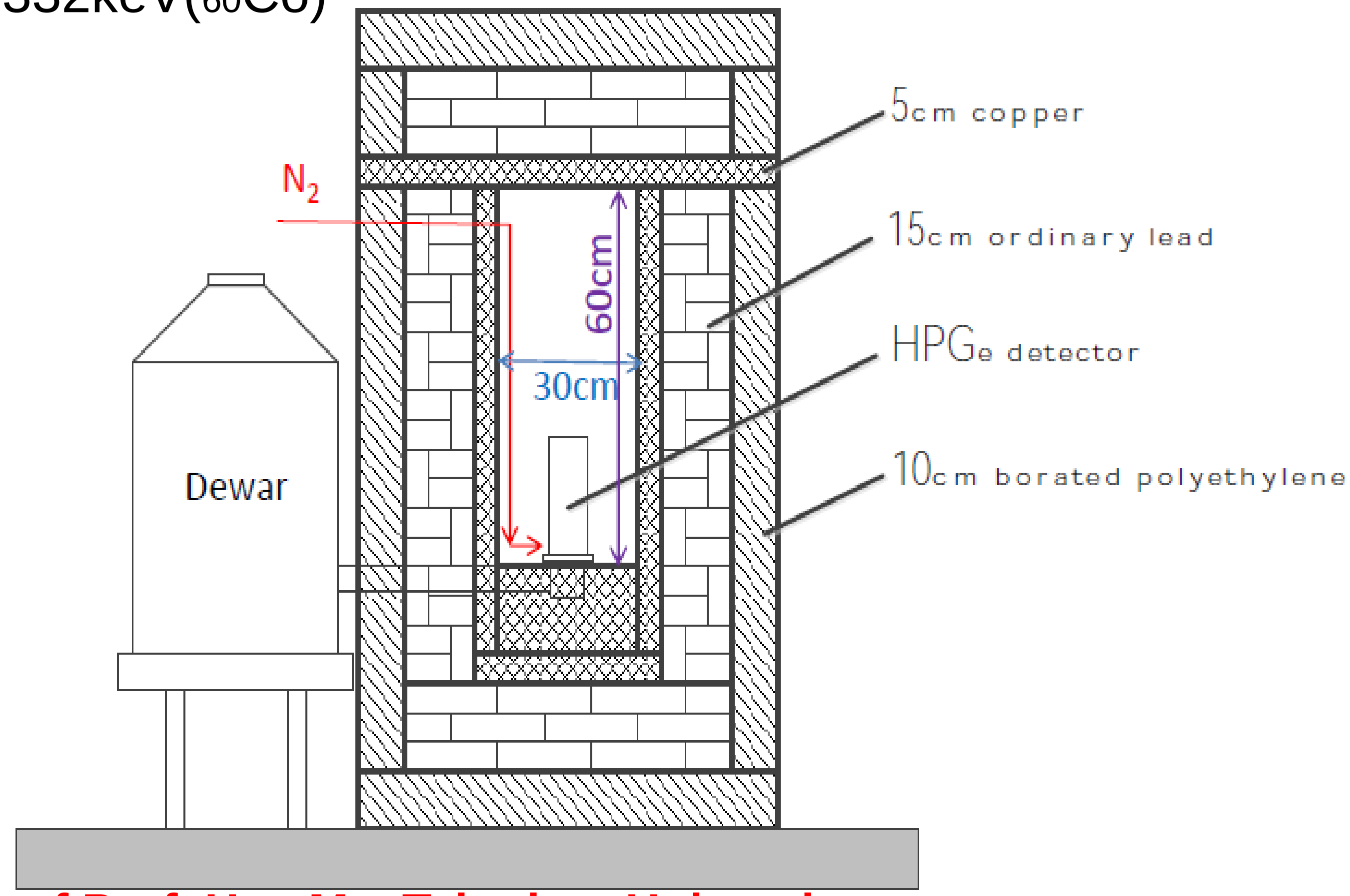


Requirements for the Shielding:

- less than one neutron or gamma induced bkg event per year
- space constraint of CJPL (Lenght 10 m and width 3,5 m)

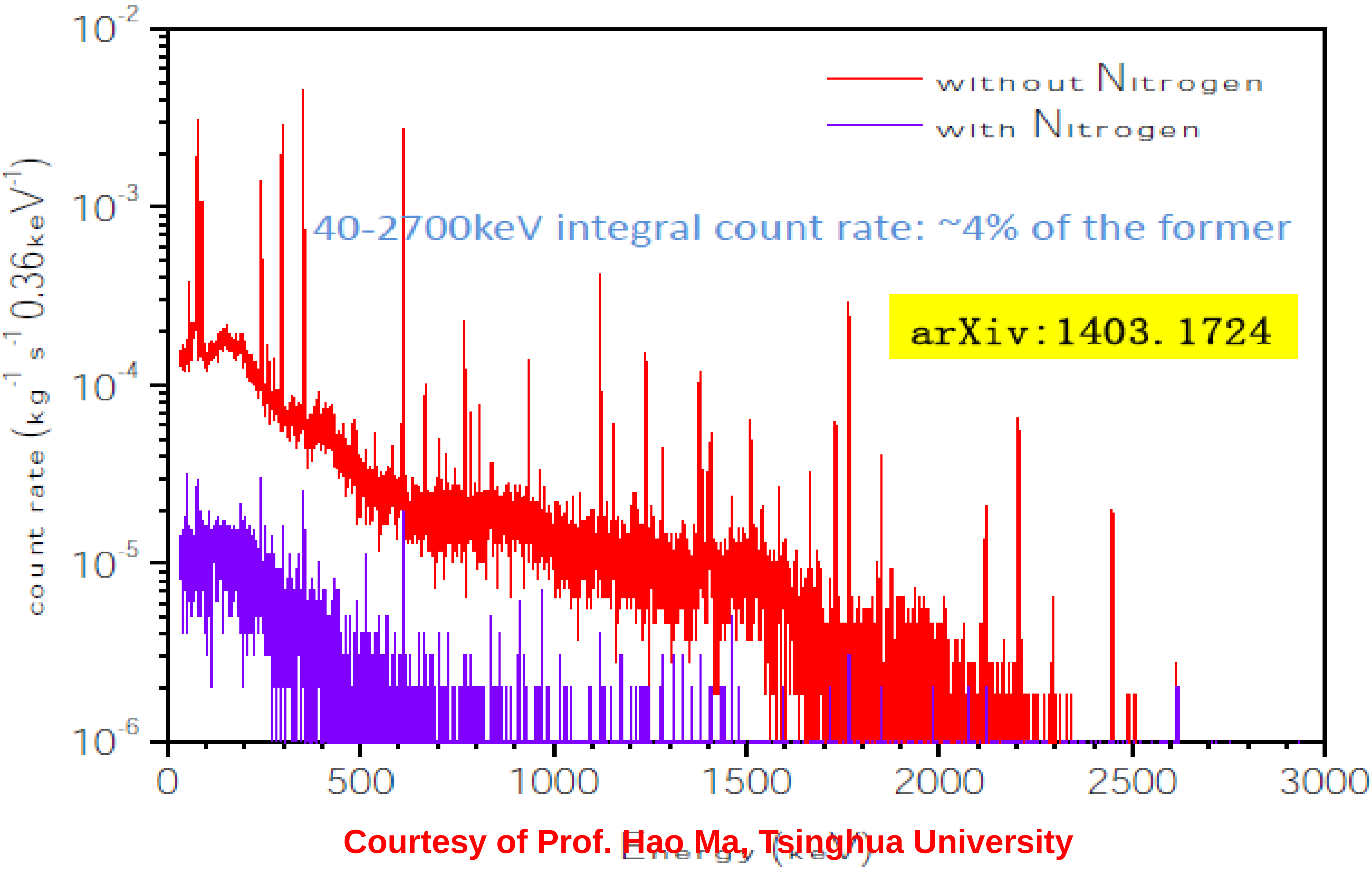
GeTHUI_Graded shielding structure

- **Detector**
  - Canberra EGC40-195-R (Ntype & U-type ULB Al cryostat)
  - Crystal： φ59.9x59.8mm (~900g)
  - Relative Efficiency:~40%
  - FWHM： 1.92keV @1332keV(^{60}Co)
  - C/P ratio： 61
- **DAQ**
  - NIMmodules
  - Software: Genie 2K
- **Efficiency**
  - MC simulation
  - Verified by certificated sources



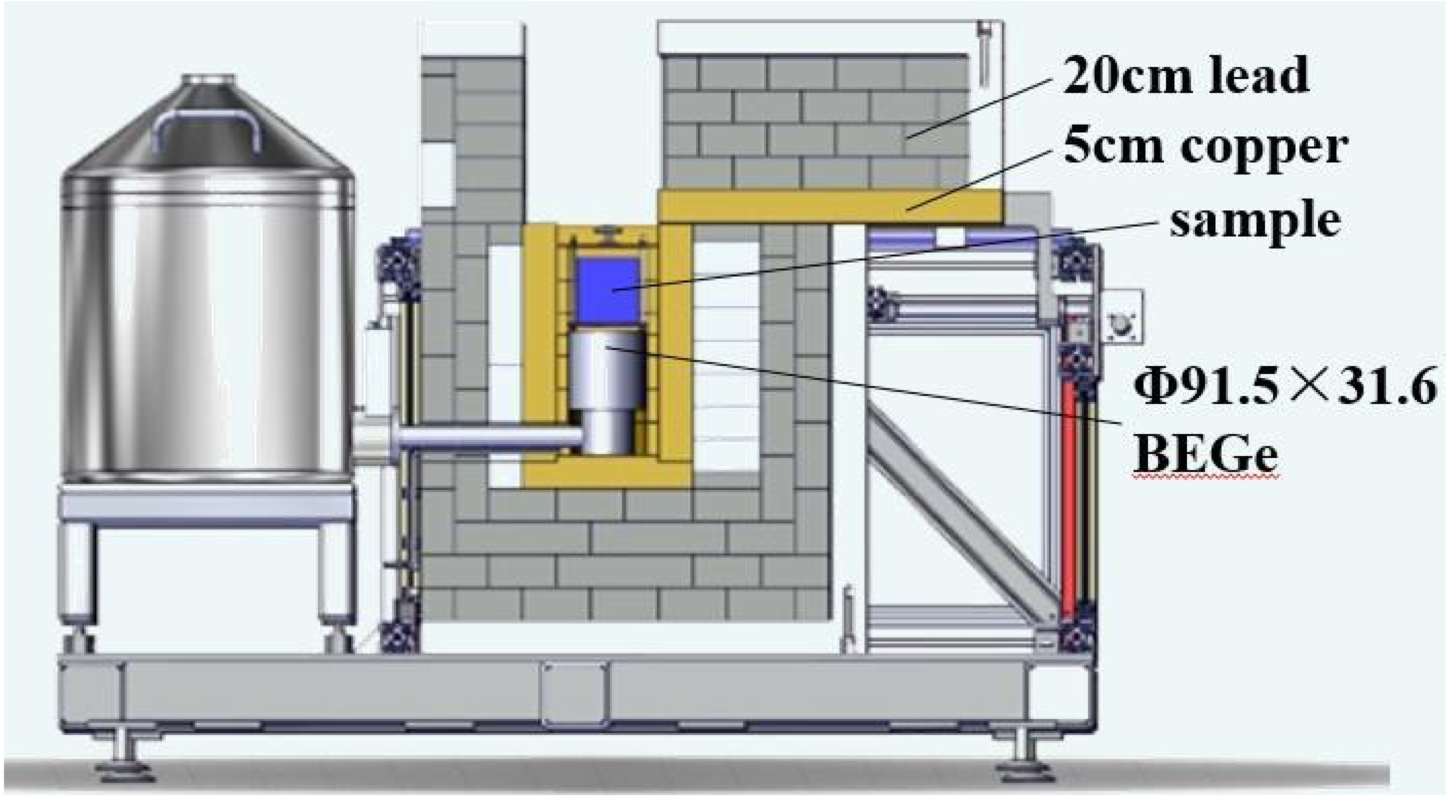
Courtesy of Prof. Hao Ma, Tsinghua University

GeTHUI_Background spectra



Courtesy of Prof. Hao Ma, Tsinghua University

GeTHUII

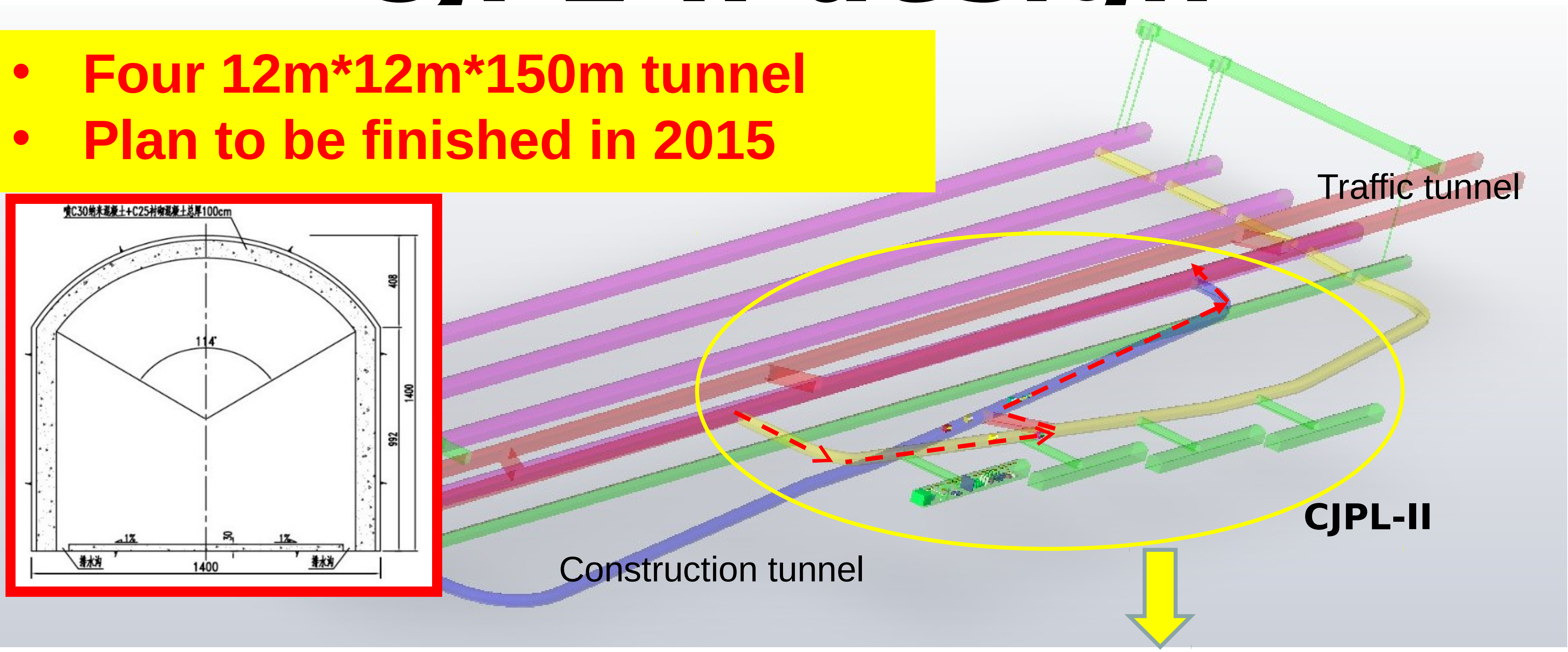


- **Detector**
  - –Canberra BEGe6530 (U-type ULB Al cryostat)
  - –Crystal： φ91.5x31.6mm (~1.1kg)
  - –Relative Eff： 67%
  - –FWHM： 1.67keV @1332keV(^{60}Co)
  - –C/P ratio： 74.2

Courtesy of Prof. Hao Ma, Tsinghua University

CJPL-II design

- Four 12m*12m*150m tunnel
- Plan to be finished in 2015



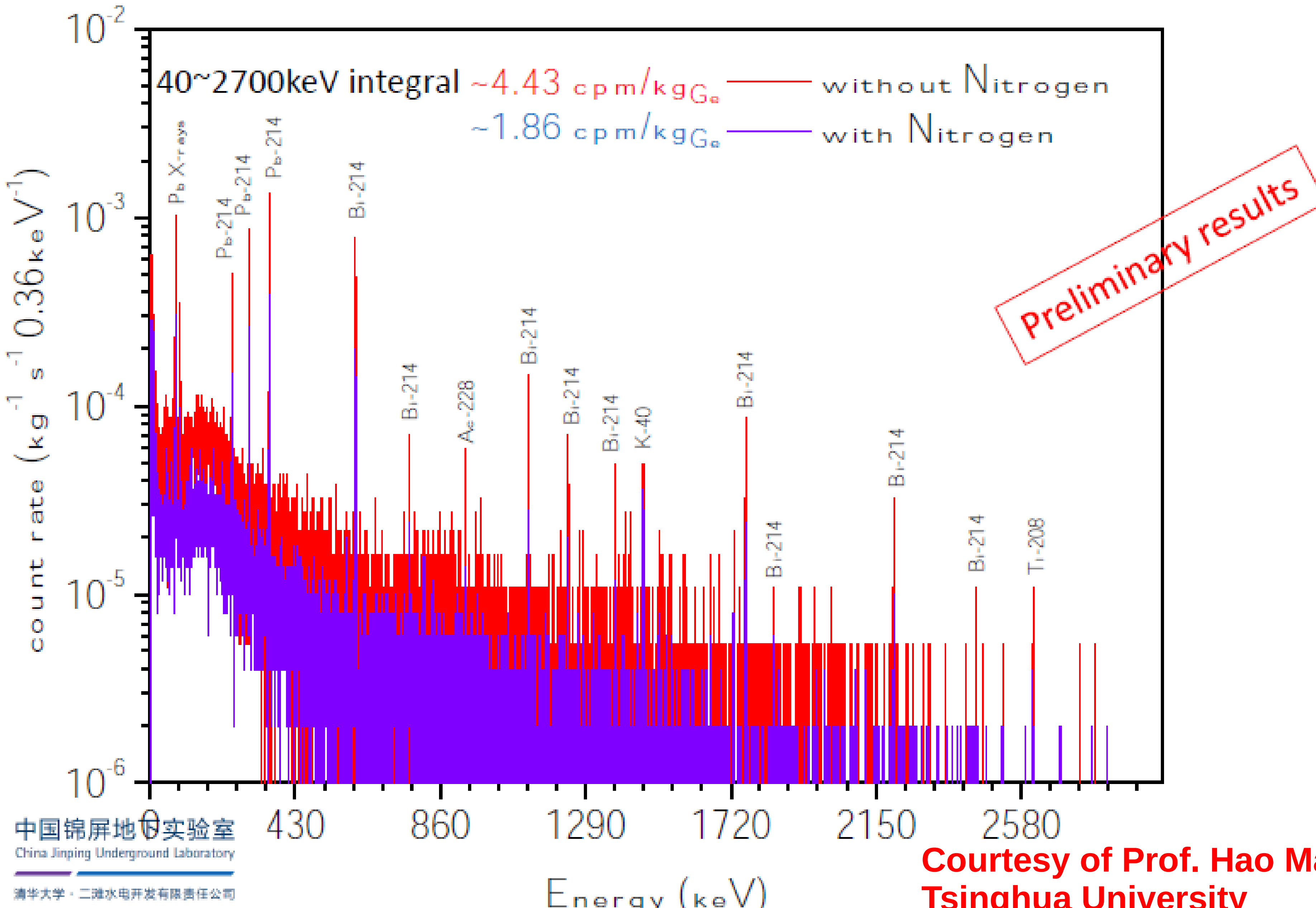
CJPL-II Hall

CJPL-II Hall

CJPL-II Hall

CJPL-II Hall

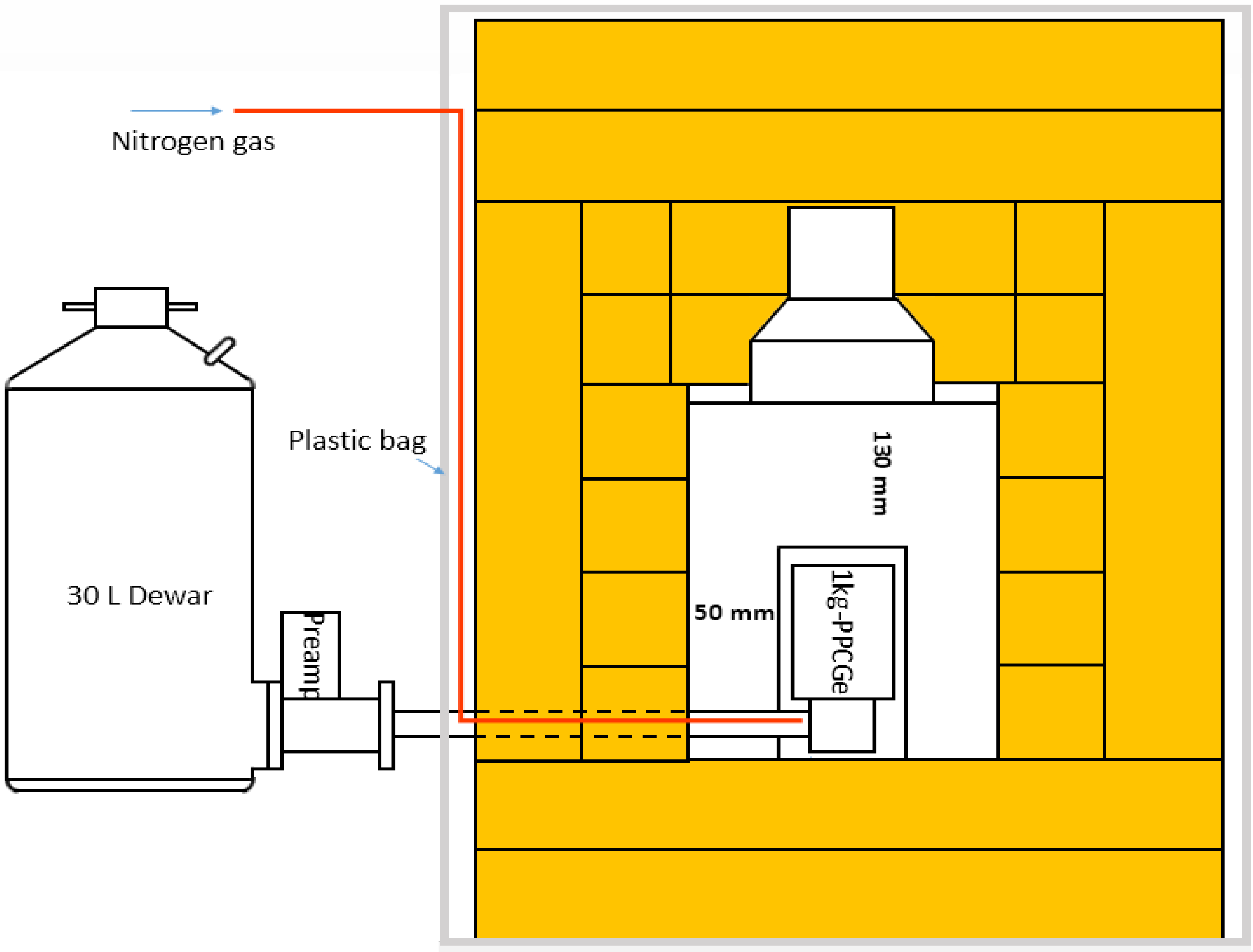
GeTHUI_Background spectra



中国锦屏地下实验室
China Jinping Underground Laboratory
清华大学・二滩水电开发有限责任公司

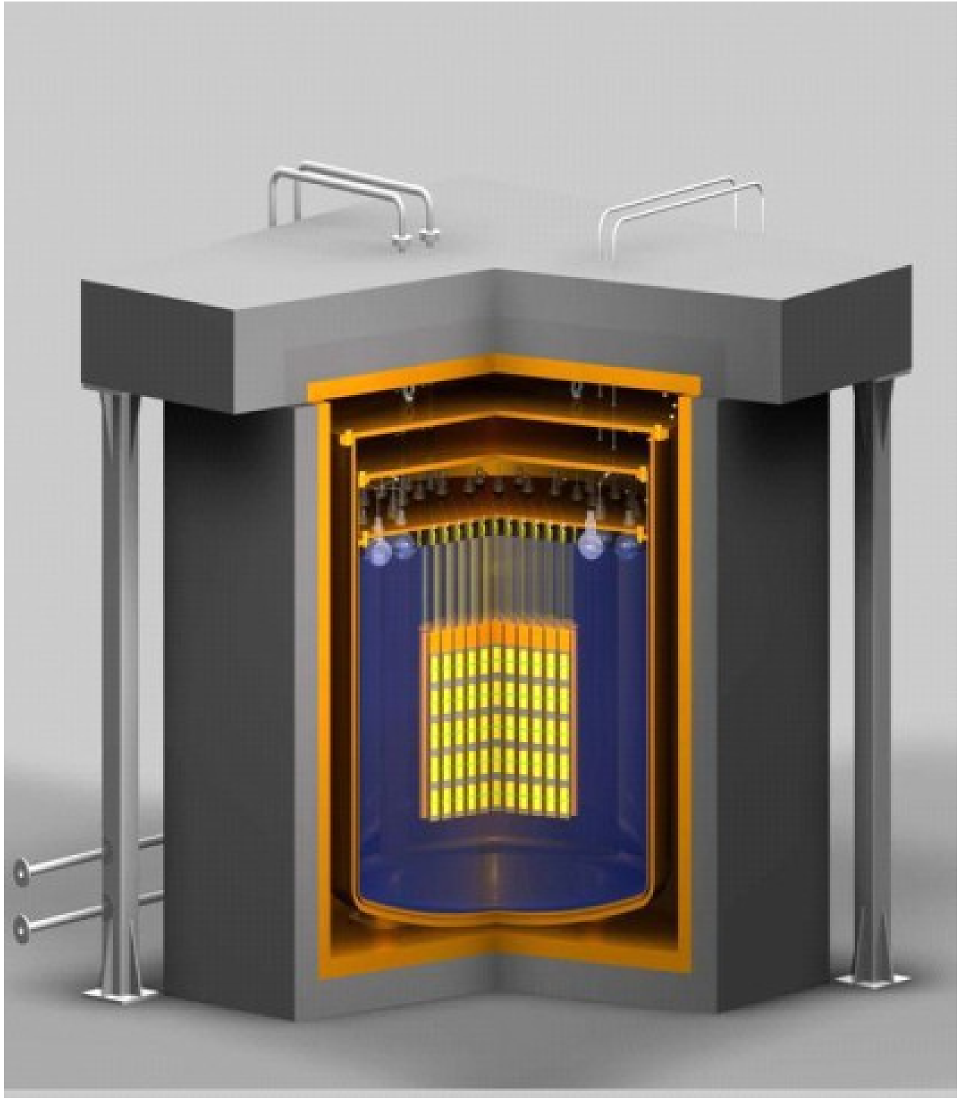
Courtesy of Prof. Hao Ma
Tsinghua University

Running experiments: CDEX



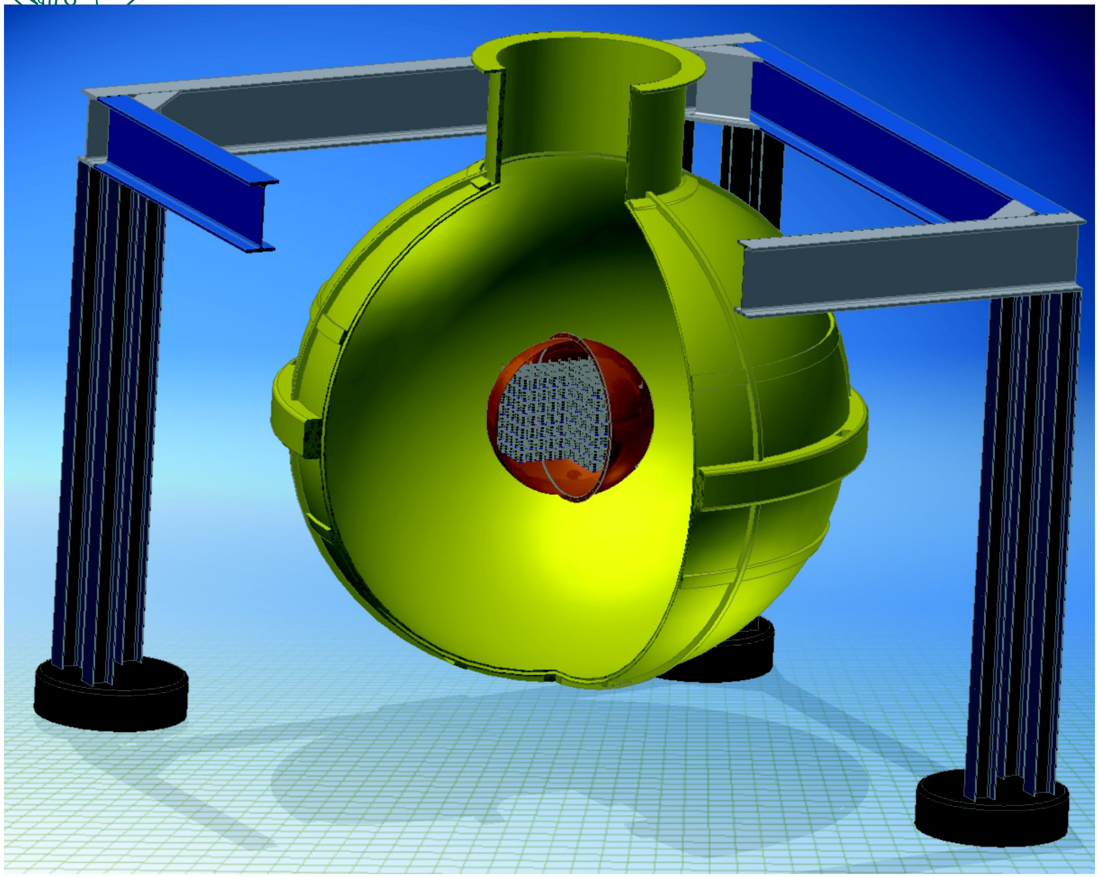
CDEX 1 Ton

- Single-site and Multi-site events discrimination possible with PCGe;
- Ge crystal growth and Ge detector fabrication by CDEX;
- It is natural to start the research beyond dark matter with the same data set of CDEX;
- The related simulation for double beta decay has been started.

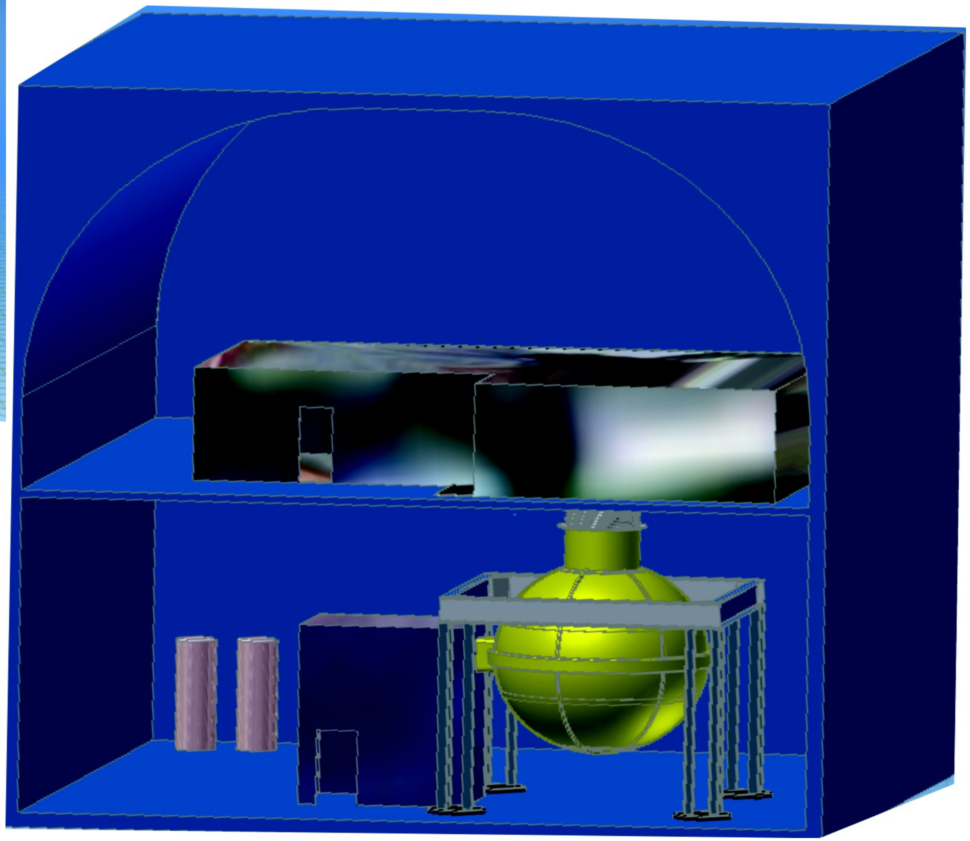


Courtesy of Prof. Qian YUE, Tsinghua University

1 Ton facility: DREAM



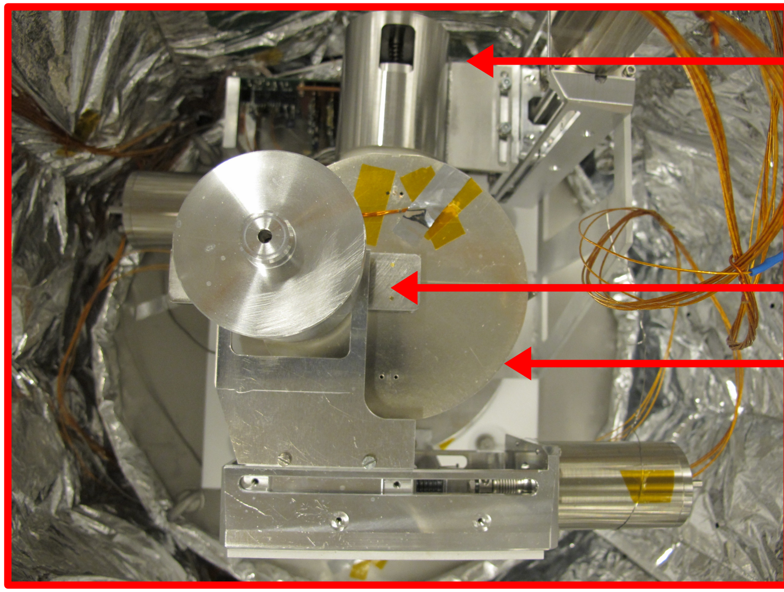
- hanging structure:
  → earthquake safe
- outer sphere filled with LN
- inner sphere filled with He or N
  → copper wall thin

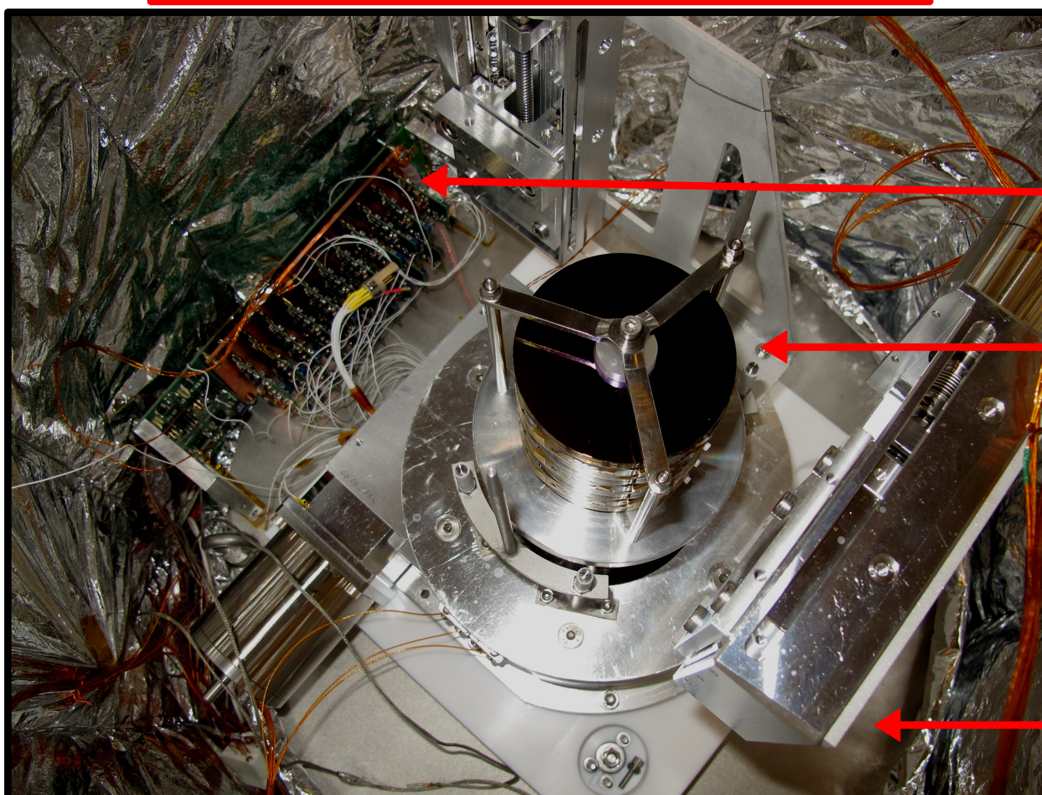


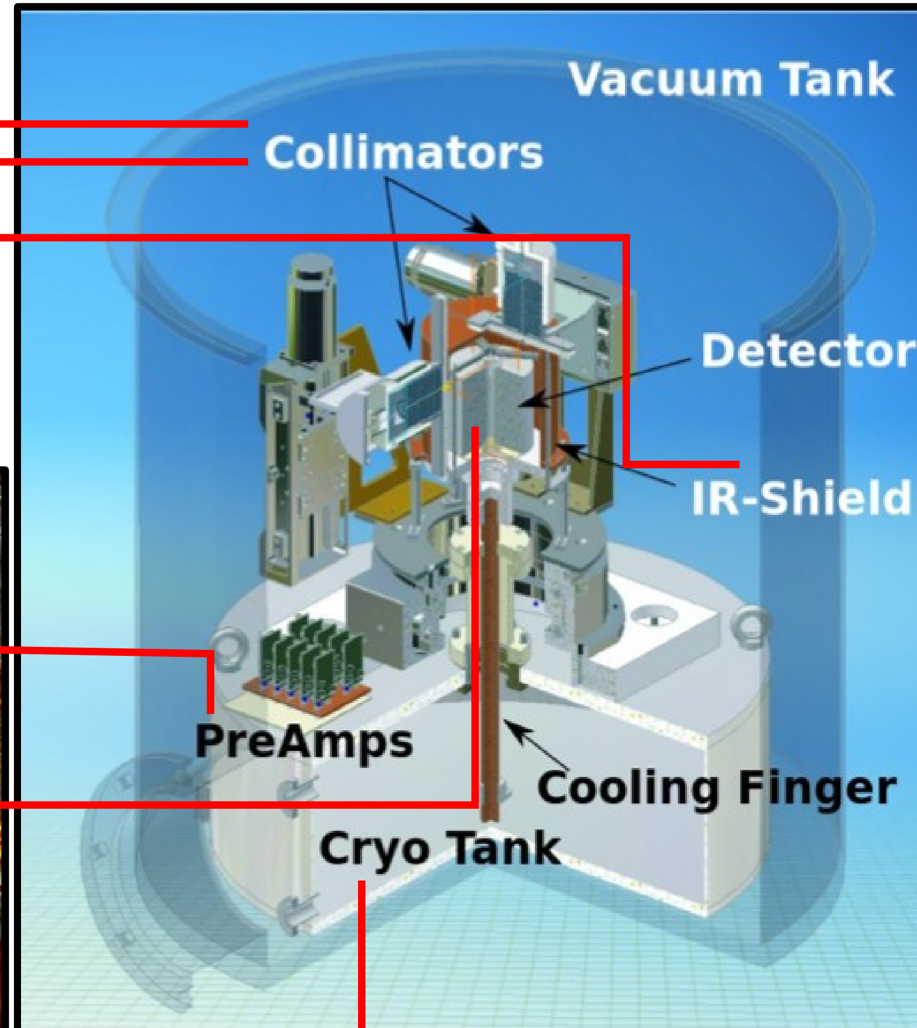
- clean room directly on top of the experimental hall
  → lower down the detector arrays

Courtesy of Dr. I. Abt

GALATEA: from the inside







Top Surface scanning

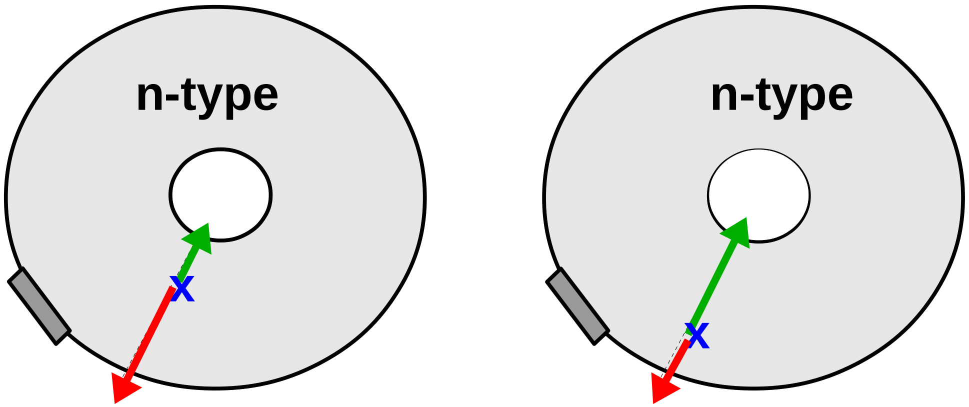
Scanning along the radius:

- fixed angle: varying the radius with steps of few mm
- check the different paths for the charge carriers
    - close to the surfaces

x point of interaction

→ electrons

→ holes



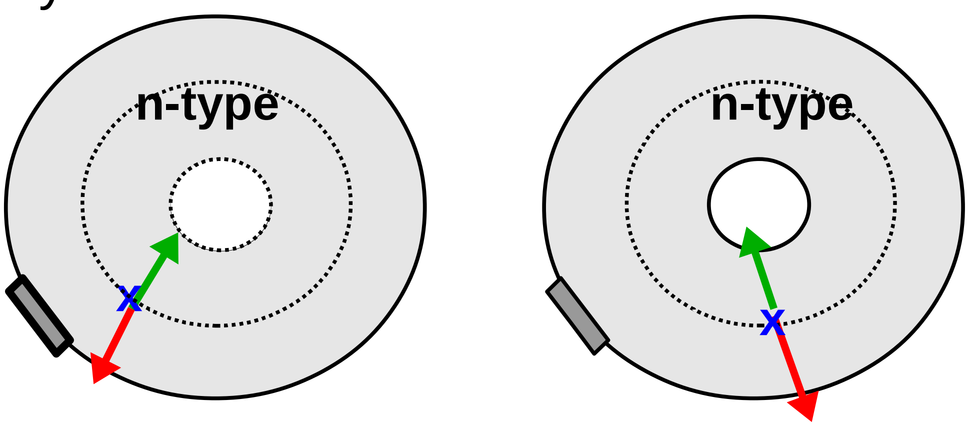
Scanning along the azimuthal angle:

- fixed radius: varying the angle with steps of few degrees
- check the effect of the Electric Field
    - change on the collection efficiency

x point of interaction

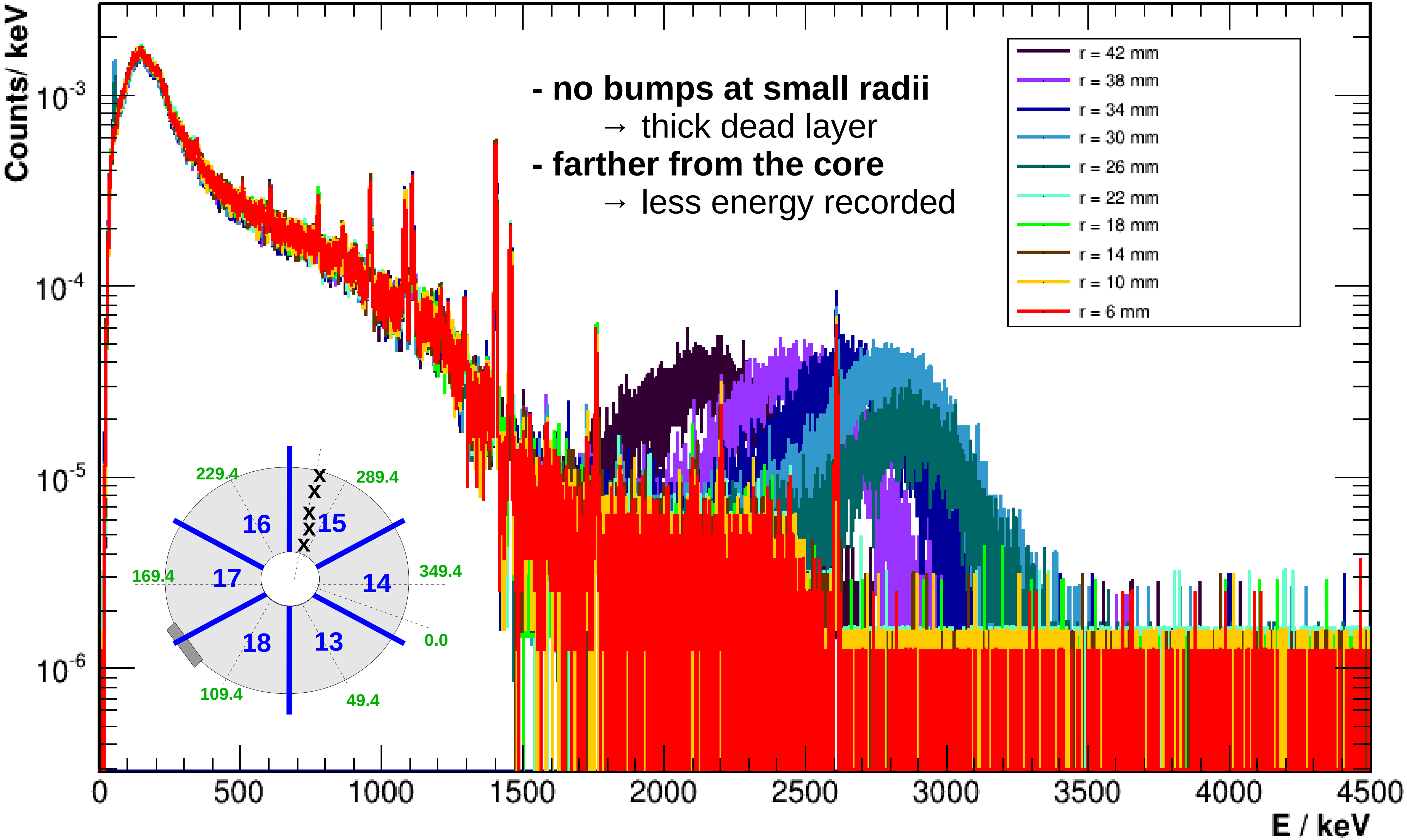
→ electrons

→ holes



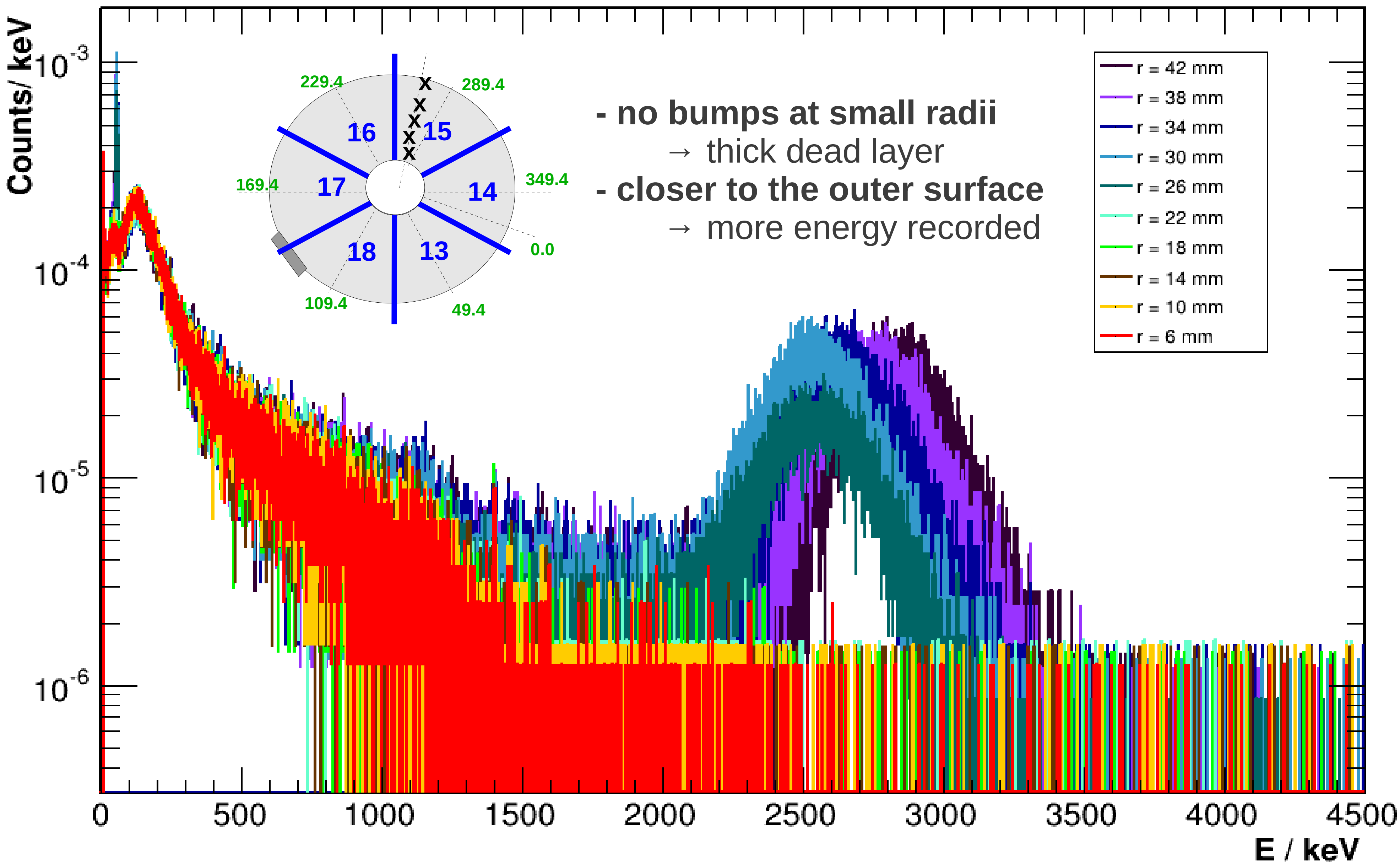
Scanning points along the radius

Core Spectra for different radius and φ= 272°

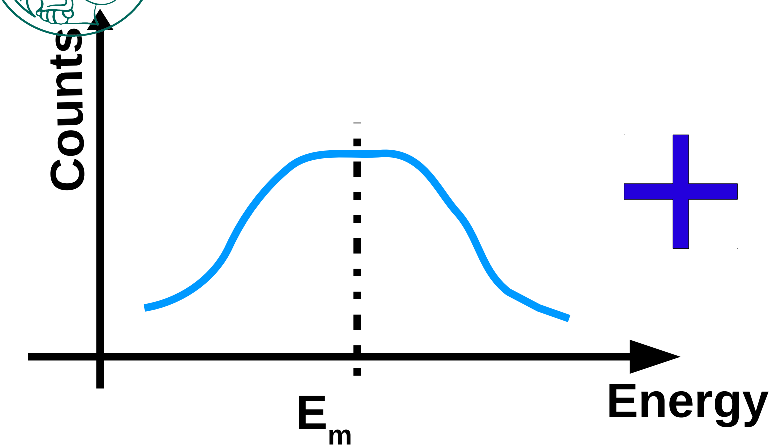


Scanning points along the radius

Seg19 Spectra for different radius and φ= 272°



Thickness of the effective dead layer



+

$$E_\alpha - E_m = \frac{\partial E}{\partial x} \cdot d$$

⇒ **?? µm**

- **E_α** → initial energy of the alpha = **5.637 MeV**

- **E_m** → measured energy of the alpha
  - fit the alpha bump with a gaussian
  - get the mean of the gaussian

- **dE/dx** → energy loss for unit of distance: = **0.2 MeV/µm**
  - by an alpha particle at 5.637 MeV
  - in Germanium

- **d** → length of the path done in a non sensitive volume
  => the **thickness of an effective dead layer**