Ge related activities @Tsinghua

- Enrichment
- Crystal growth
- Detector fabrication
- Front-end electronics development

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Ge enrichment (1)

- Parallel with CDEX dark matter experiment, Ge enrichment has also been pursued by THU;
- THU DEP has set the major of isotope seperation for more then 60 years;
- Small amount of machines had installed in our department for students training and studies;

Ge enrichment (2)

- The team has much experience on the enrichment of many isotopes including Mo-100, Ge-76, ……;
  - GeF_4, gas centrifuge seperation
  - Abun. of Ge-76, >13%
- The team has close relationship with huge factories with millions of centrifuge machine;
- The enrichment power in China is good enough for tonne-scale Ge-76 enrichment.

What more…

- The enriched materials could be shipped to CJPL for storage in less then 24 hours by train and truck with reasonable lead shielding
  - this will decrease the exposure time of the enriched material dramatically;
- Ge crystal growth in CJPL could definitely limit the increase of some long-life radioactive isotopes to a negligible level:
  - H-3 for DM
  - Ge-68, Co-60 for both DM and DBD.
- The other Ge isotopes except Ge-76 could still be used to grow crystal and fabricate HPGe detector for DM.
  - This will dramatically decrease the whole cost for the project

Crystal growth: major facilities

Zone refining machine

Czochralski machine

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Crystal growth: major facilities

Cleaning Room

Hall Effect Measurement System

Hydrogen Generator and Purifier

Metallurgical Microscope

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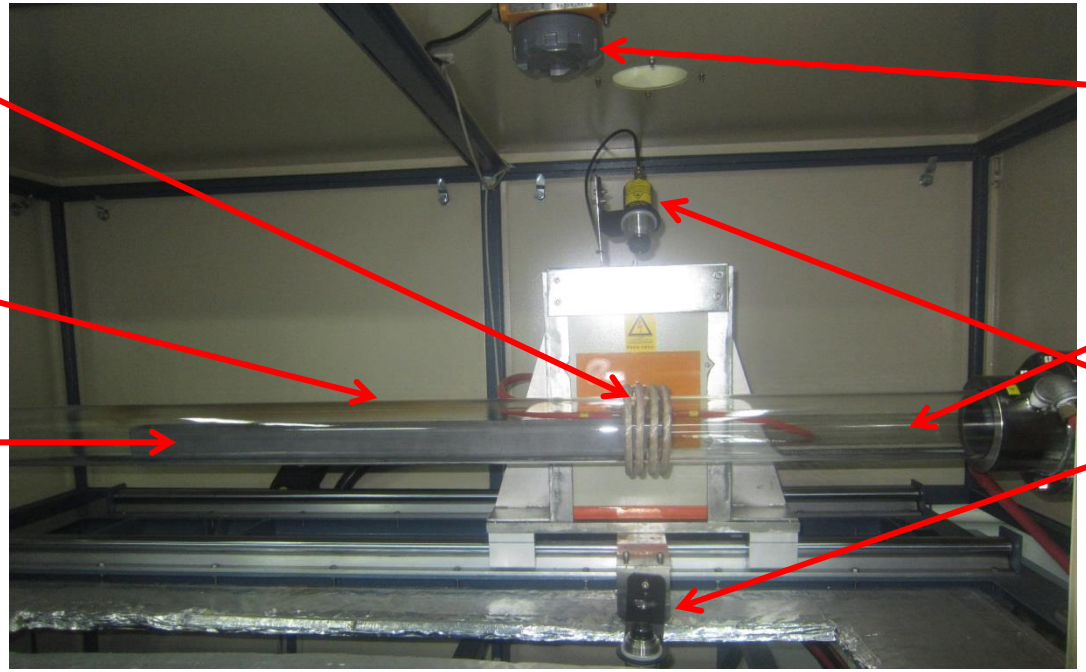
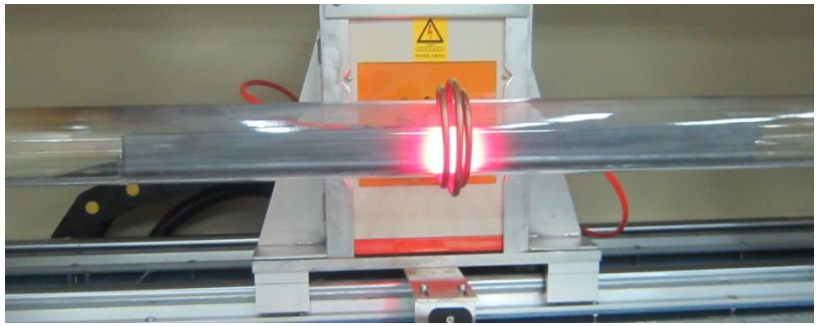
Zone refining of polycrystalline germanium

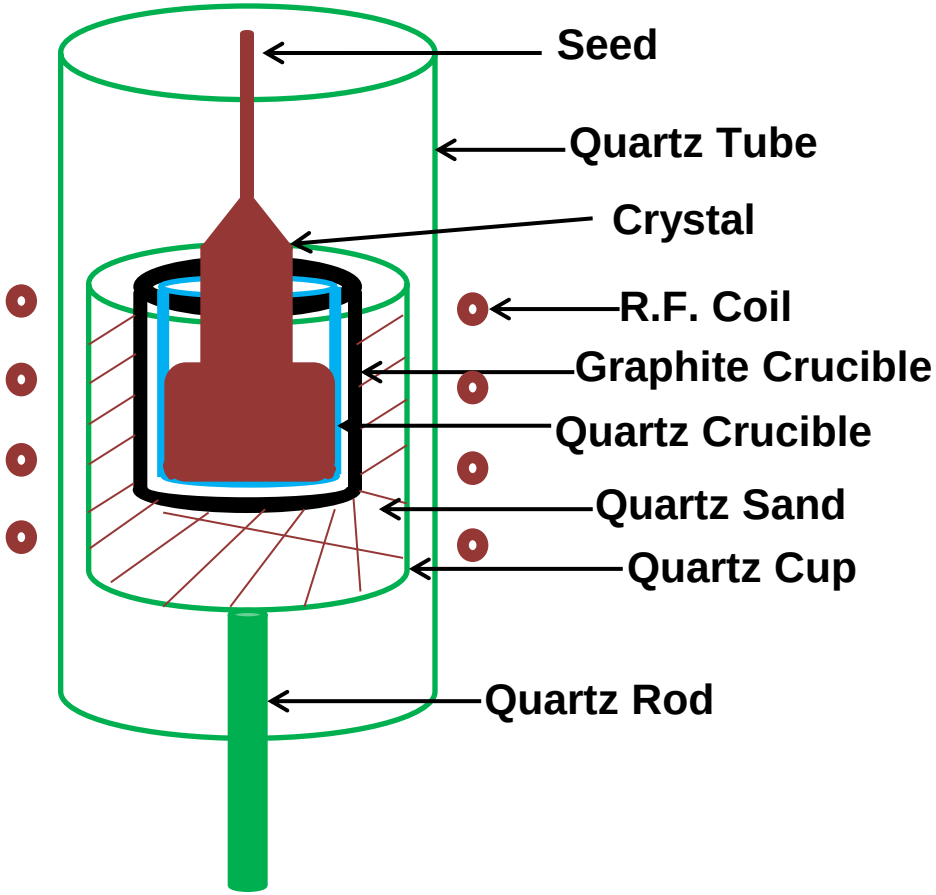




Czochralski growth of high purity germanium single crystal

Growth process:

- Put germanium material into the quartz crucible
- Increase temperature to melt the germanium material
- Insert the germanium seed crystal
- Pulling the seed crystal
- Adjust the temperature to decrease/increase the diameter



Grown samples of germanium single crystal

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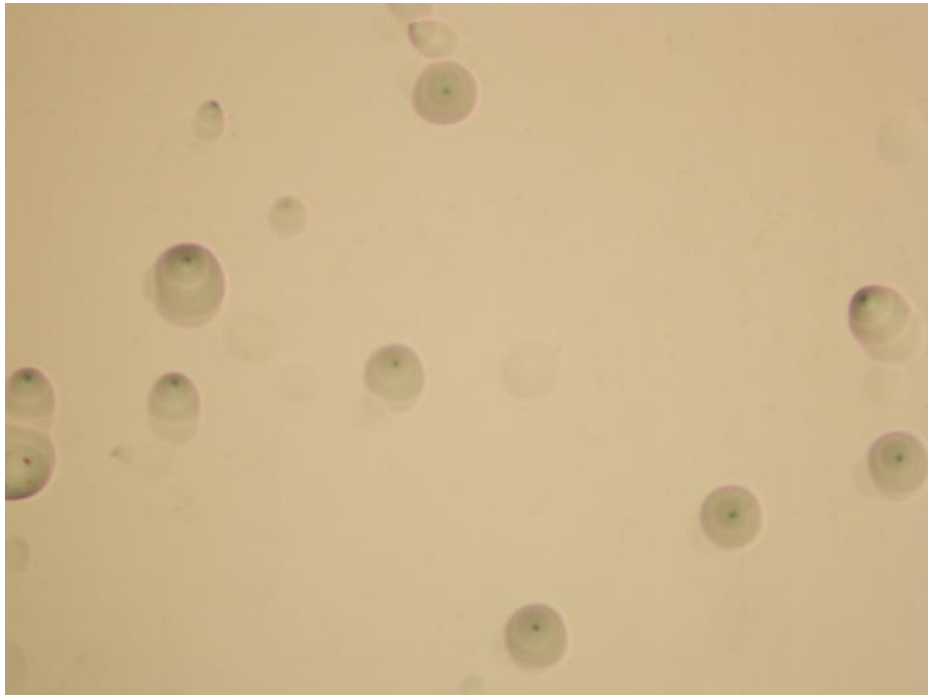
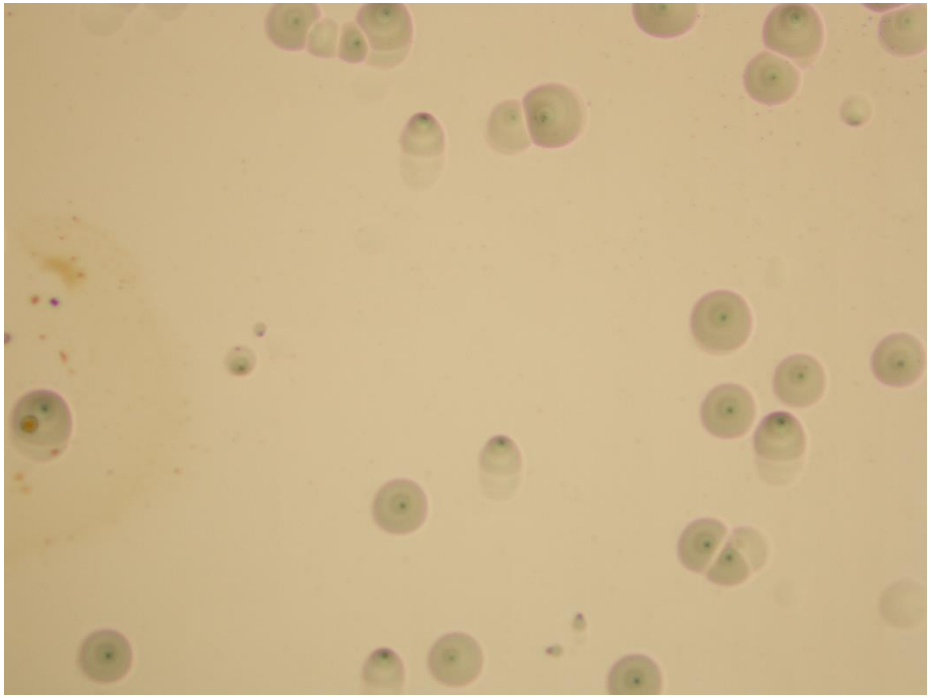
Dislocation measurement of germanium single crystal

0.003 cm^2 at center



0.003 cm^2 at edge



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Crystal Growth: Summary & planning

- Summary:
  - A majority of facilities are prepared for purity refining, crystal growing, quality measuring.
  - The purity of 10 N can be obtained.
  - The dislocation is 150,000/cm^2. However, the uniformity is bad.
- In future, we will continue to:
  - To purify the germanium material by using high purity quartz boat instead of graphite boat and optimizing the parameters.
  - To decrease the dislocation density by optimizing the parameters of crystal growth.

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Facilities @ THU for HPGe Detector

- Clean room

Vacuum Coating Machine

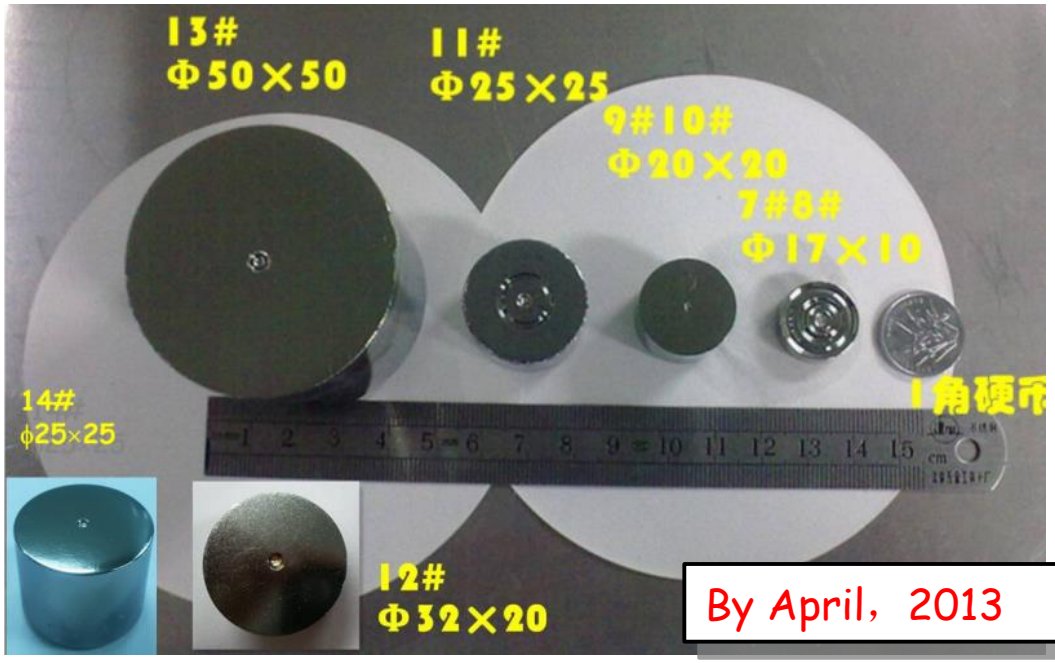
Sputtering Device

- Chemical Lab

- Mechanical workshop

- Test corner

Crystals Processed



New members recently:

- PCGes:
  - 15#, 16#: ø 25mm×25mm (~65g)
  - 18#, 19#: ø 50mm×50mm (~500g)
    - Good performance
    - Will be used in CDEX-10X
- BEGe:
  - 21#: ø 50mm×30mm

New surface treatment method and electrode configuration developed:

- Good performance: low leakage current, good long-term stability
- Easy to handle and assemble

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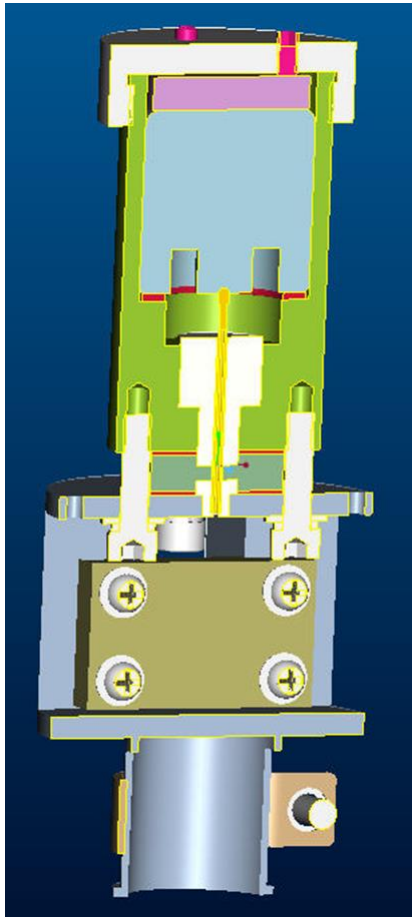
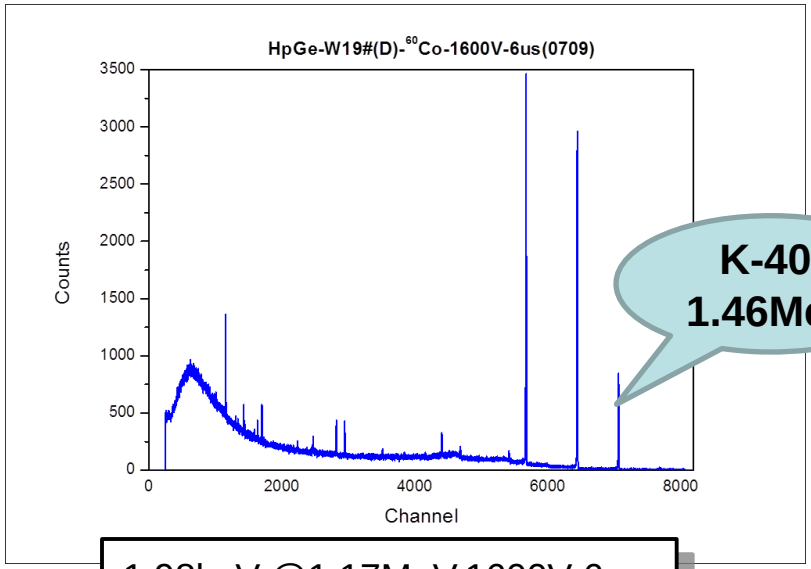
Progress in PCGe detector fabrication

- PCGe Detector-19# (ø50mm)



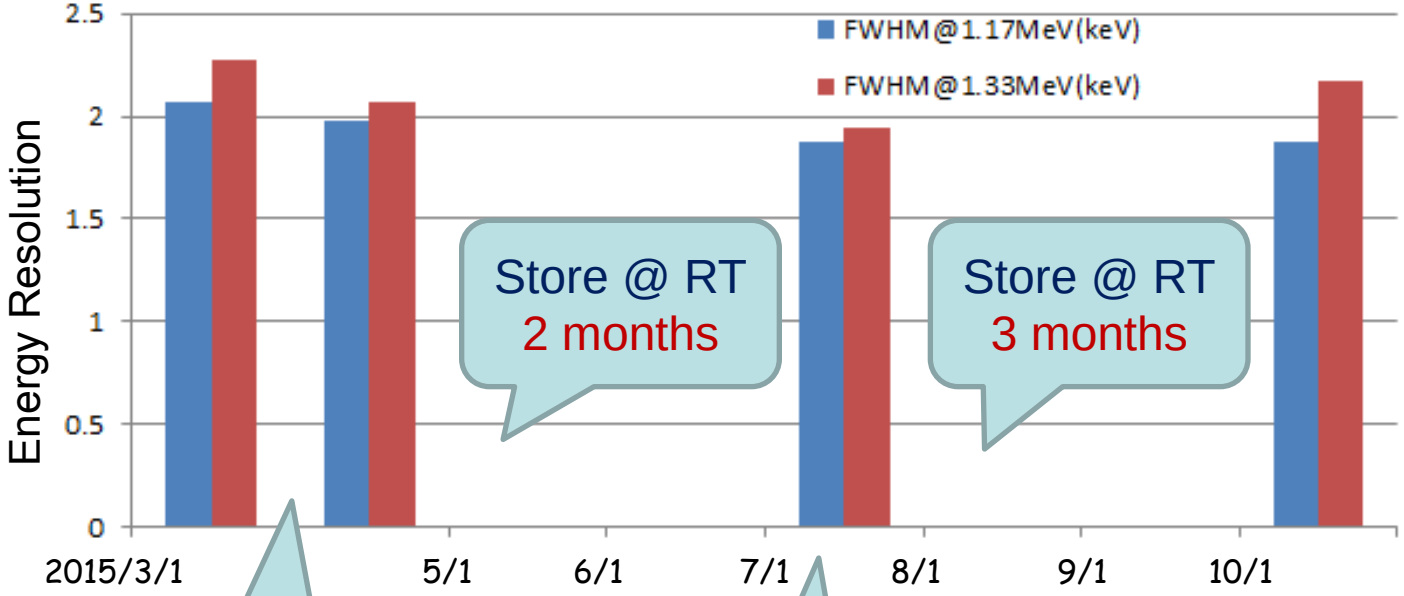
- Very good performance:

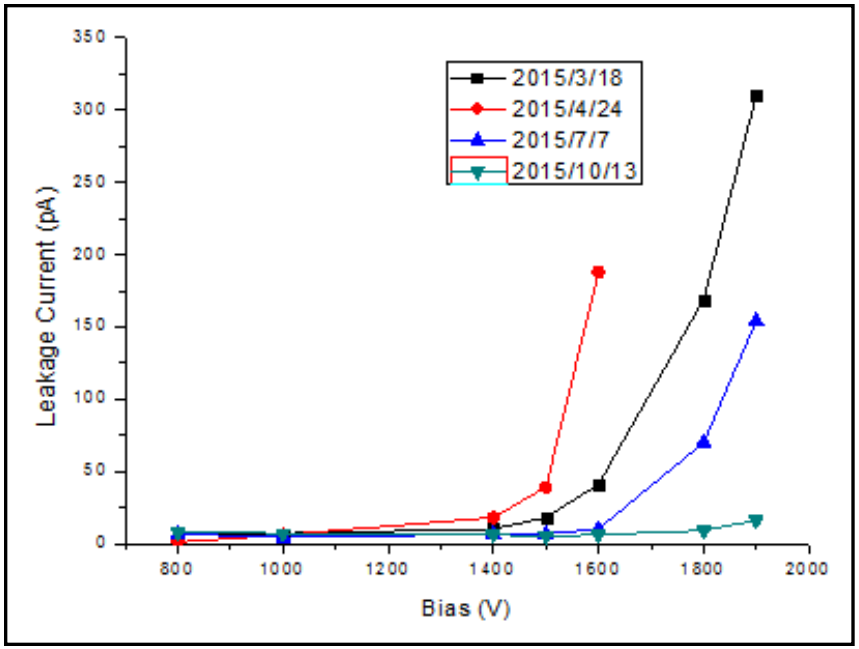
Bias (V)	800	900	1000	1100	1200
Leakage Current (pA)	1	3	6	7	13
Bias (V)	1300	1400	1500	1600	1700
Leakage Current (pA)	19	39	97	188	922



1.98keV @1.17MeV,1600V-6us
2.12keV @1.33MeV,1600V-6us

19# Detector: Thermal Cycle Test





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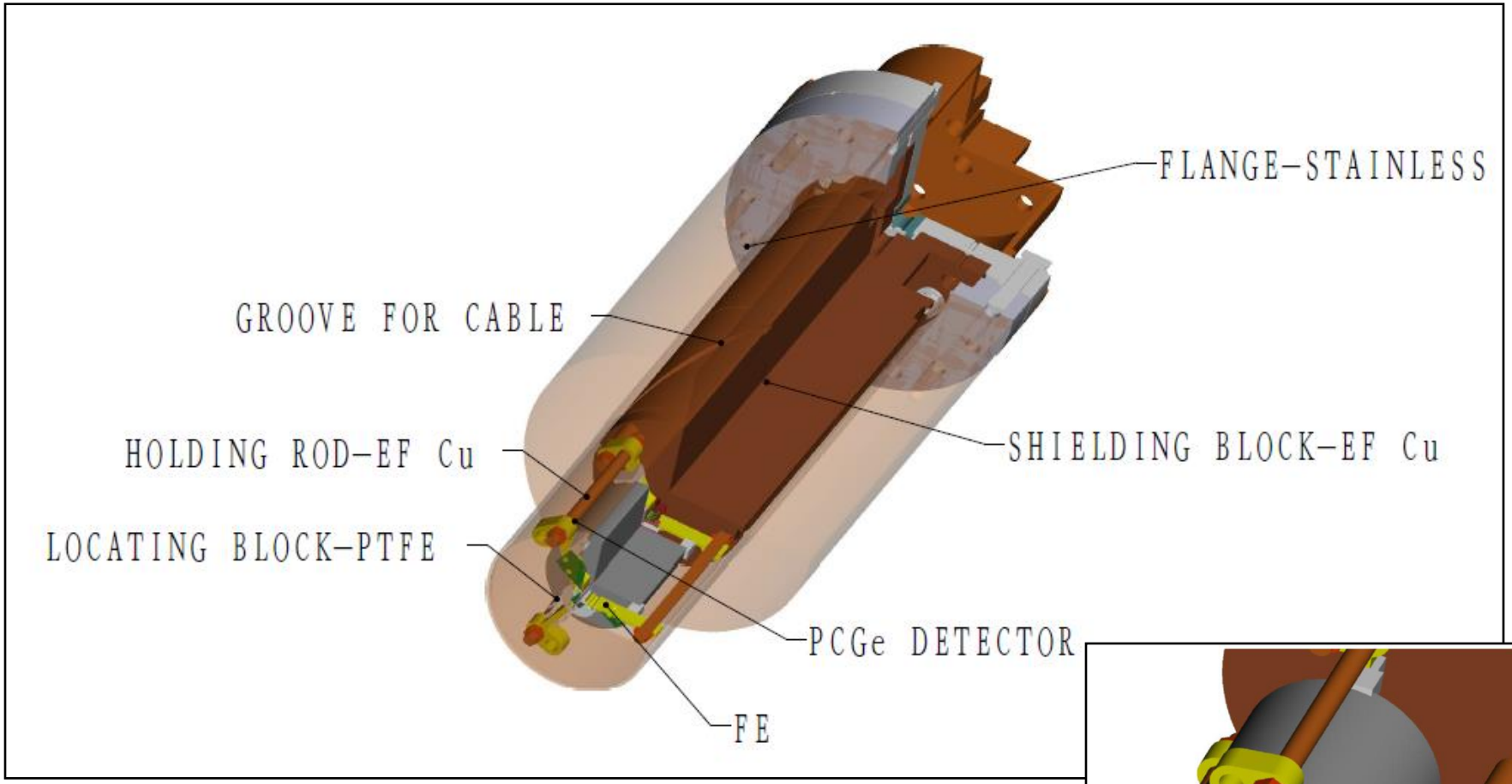
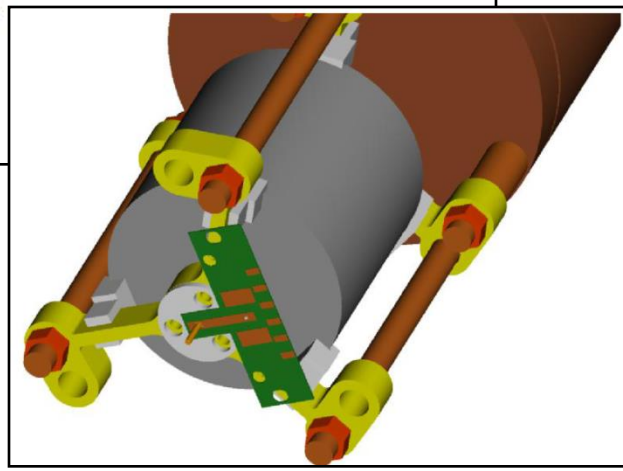
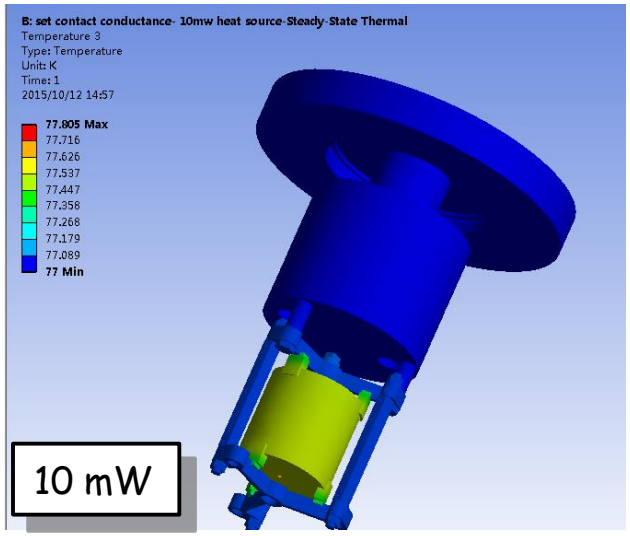
CDEX-10X design: mechanical

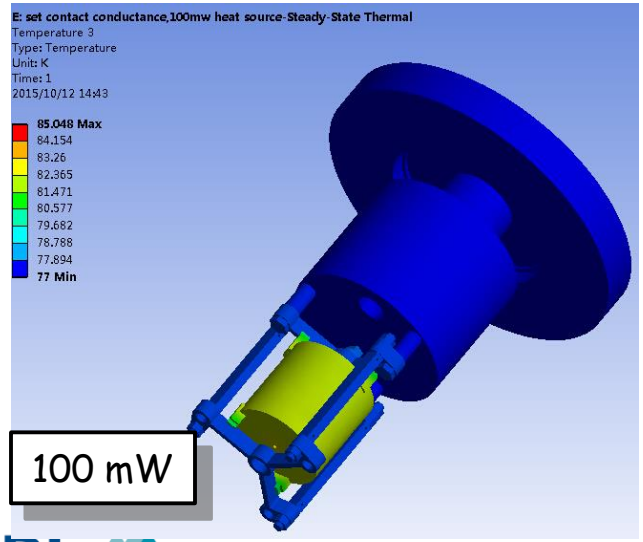




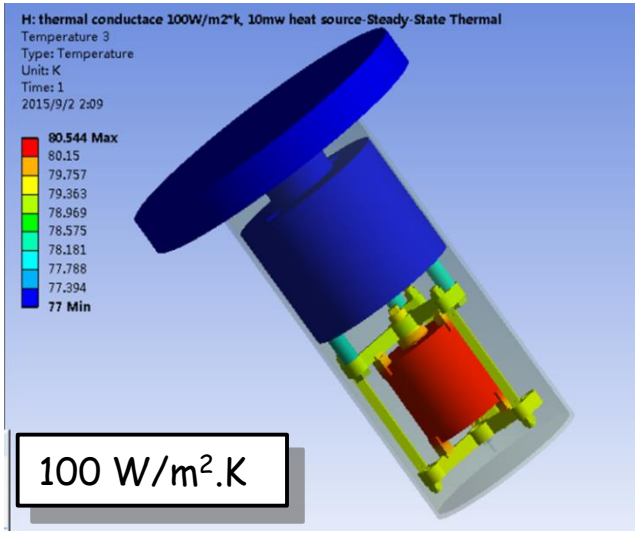
CDEX-10X design: Thermal Simulation Analysis

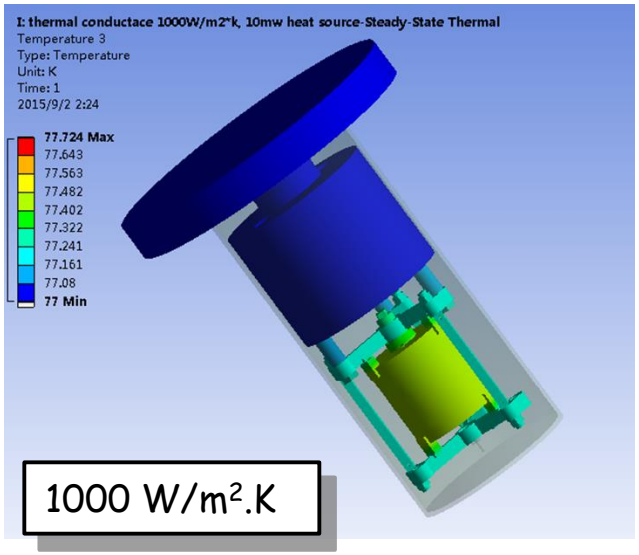
- Different heat source：





- Different thermal conductance





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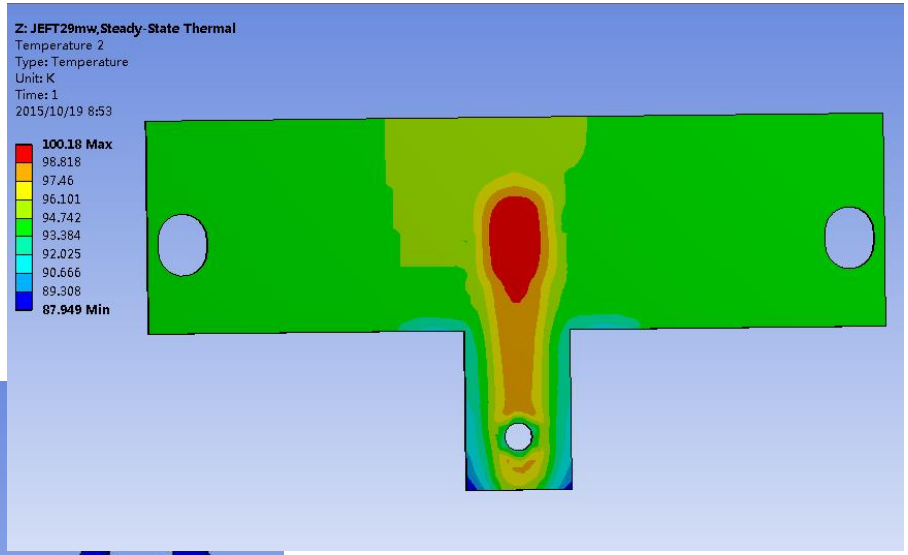
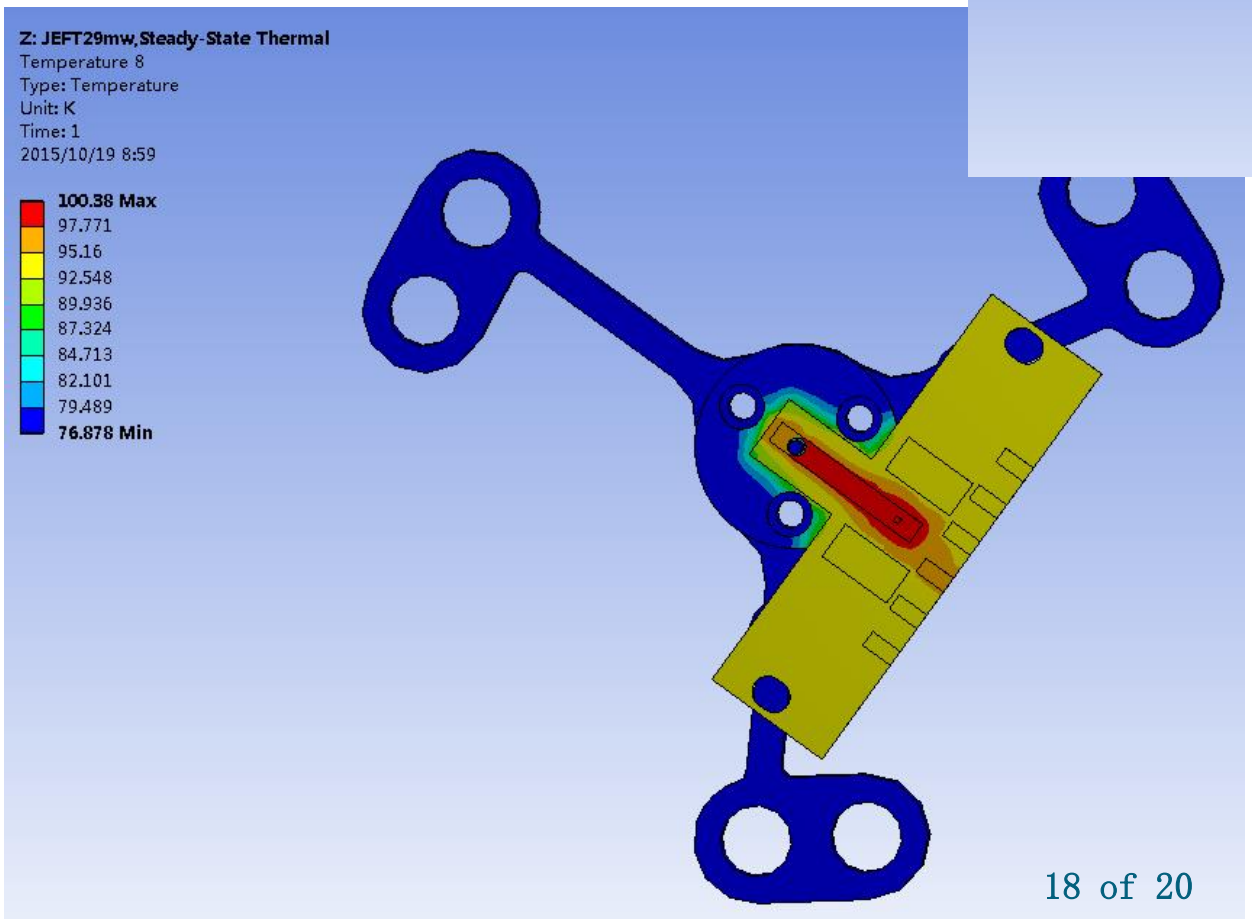
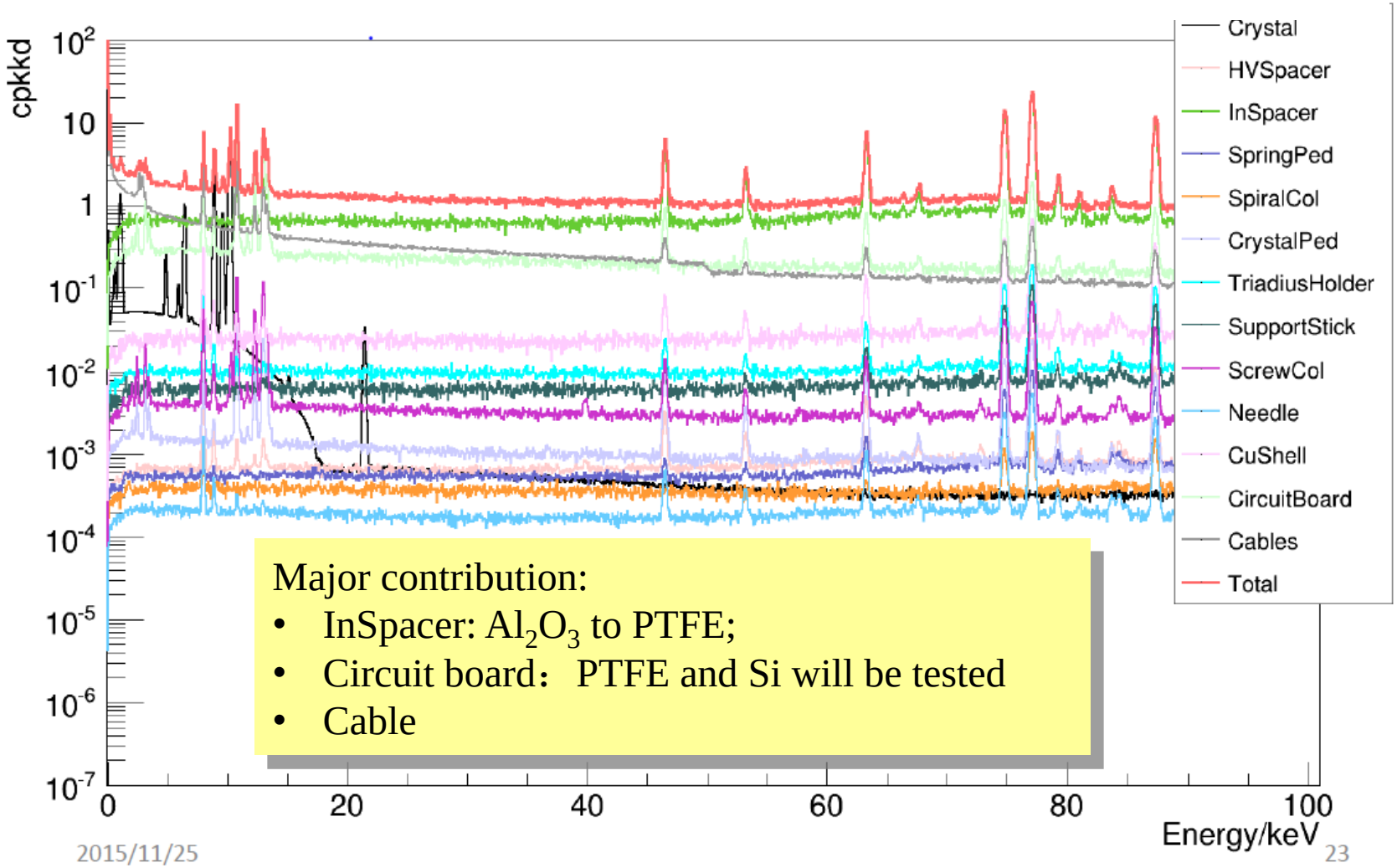
CDEX-10X design: Thermal Simulation Analysis (2)





29mW is needed for JFET to be heated to 100k

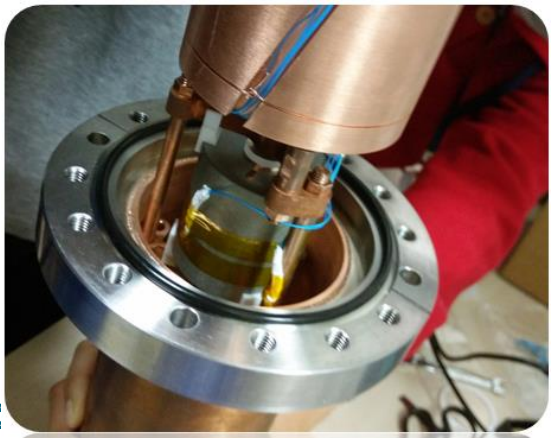
CDEX-10X background simulation & optimization



Major contribution:

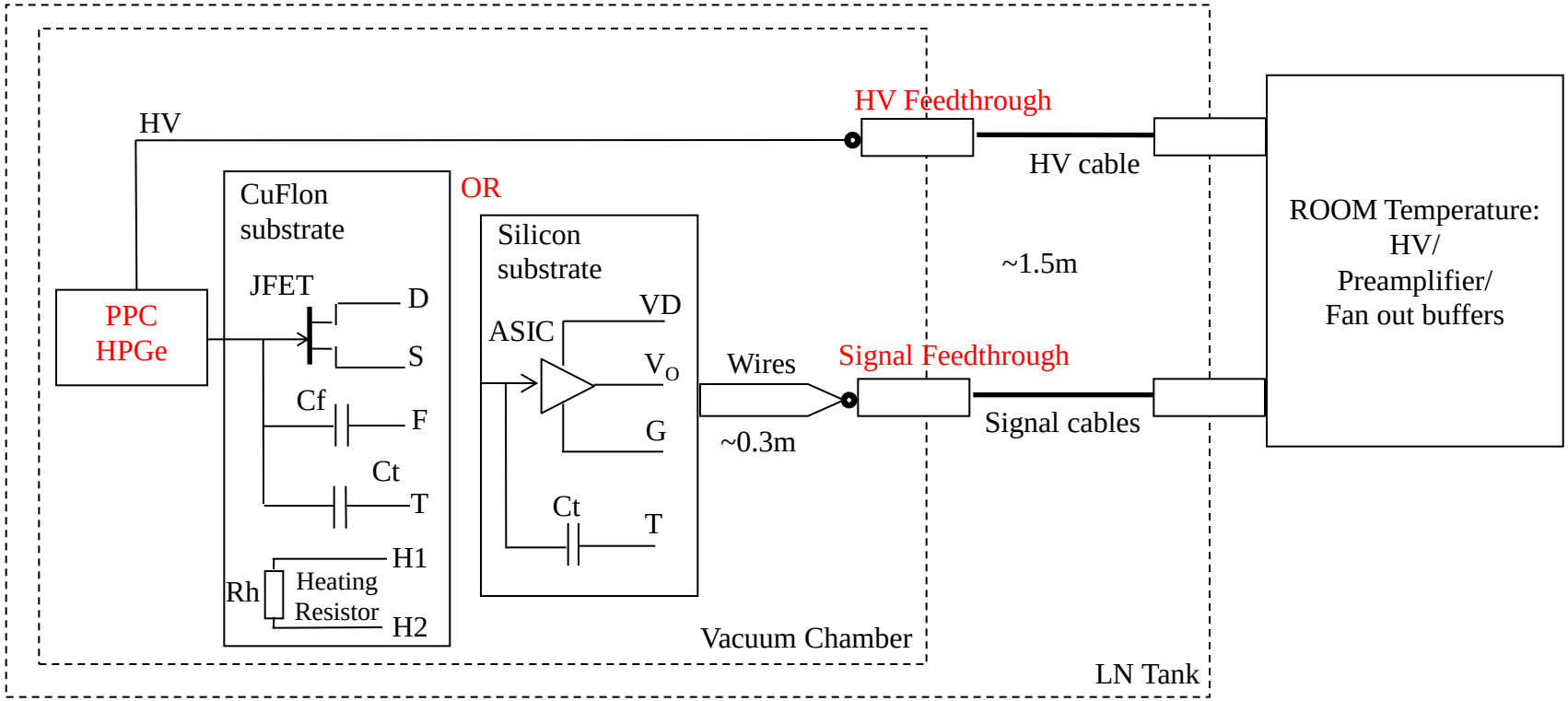
- InSpacer: Al_2O_3 to PTFE;
- Circuit board： PTFE and Si will be tested
- Cable

CDEX-10X assembly



Current FE electronics design

- Readout Scheme



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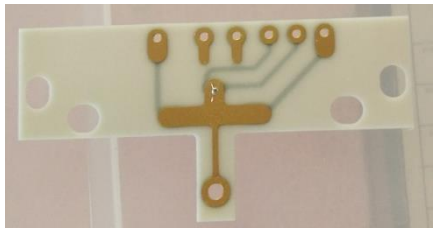
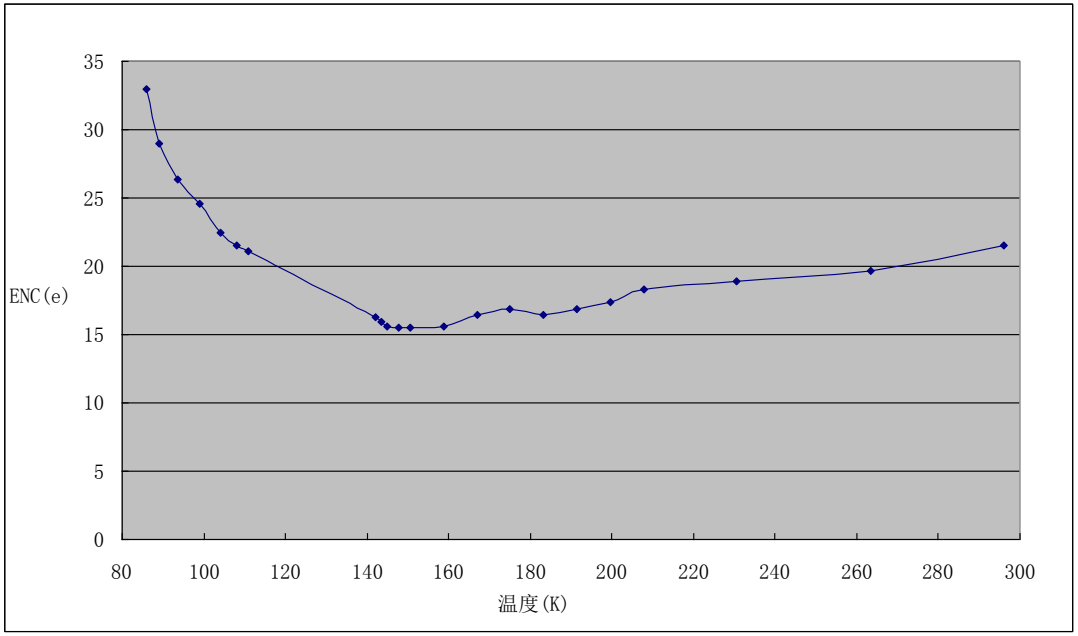
Test Results

- JFET based readout



JFET bonded on CuFlon substrate

Test Setup



ENC @ Cd=0 vs. Temperature

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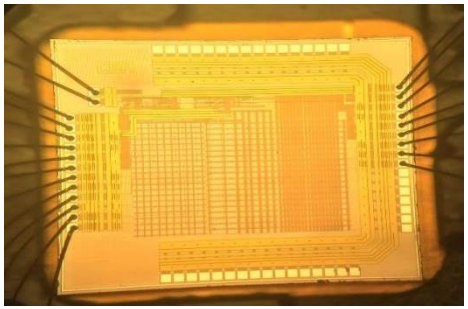
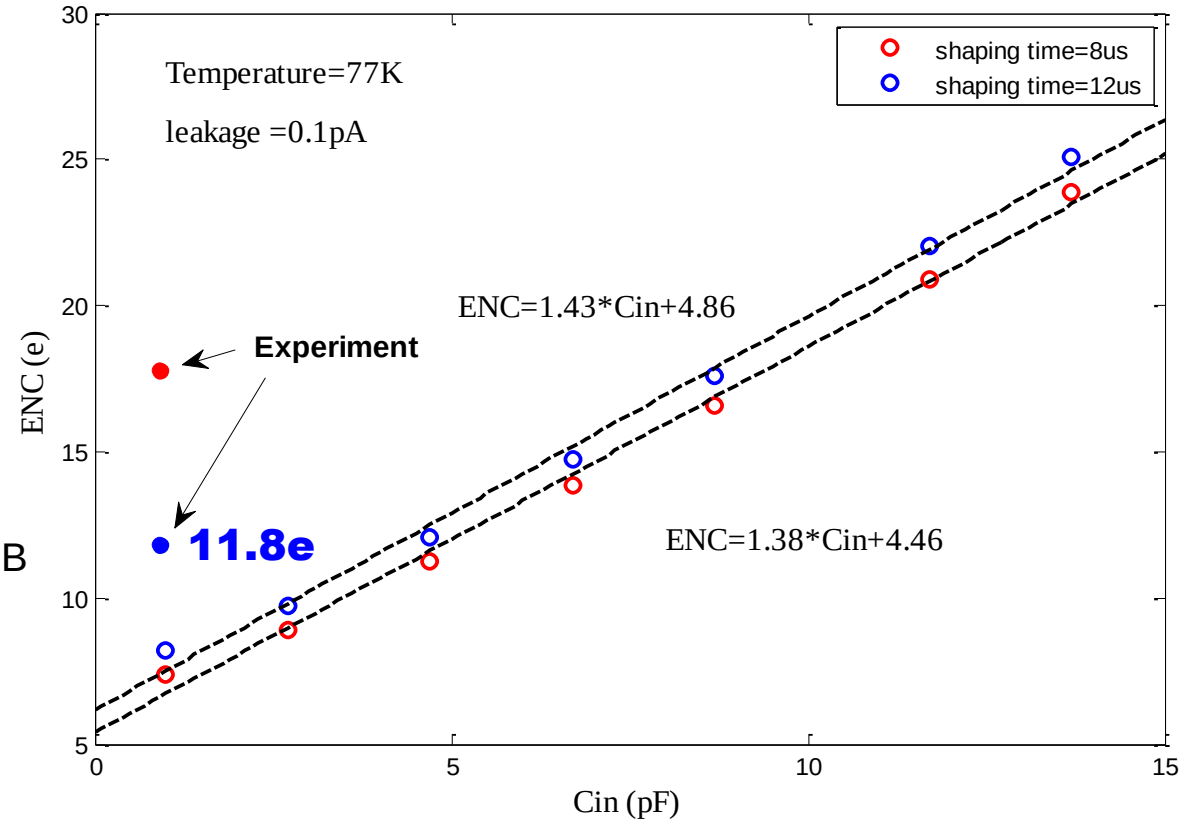
Test Results

- CMOS ASIC based readout



Preamp ASIC bonded on Test PCB



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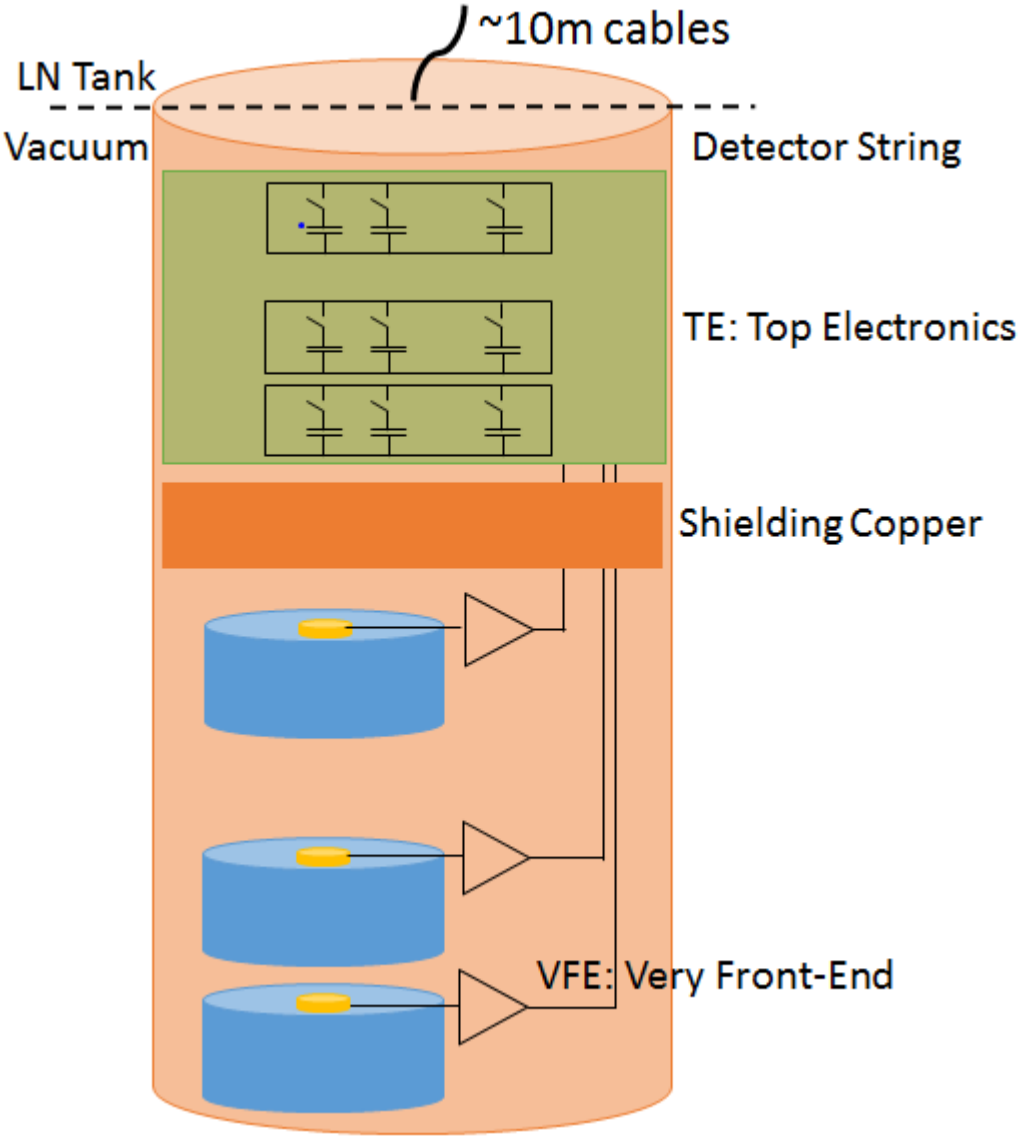
Future Plan for large scale readout

- Future electronics consist of VFE and TE for each detector string
- Two options for VFE and TE:
  - JFET based: FE - JFET, TE - Cryogenic preamplifier
  - ASIC based: VFE – ASIC CSA, TE – SCA waveform recorder
- Technical challenges:
  - Cryogenic preamplifier for JFET and waveform recorder
  - Power delivery and signal cables without introducing interference and crosstalk
  - Low radioactive background materials for electronics components, substrate and cables



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Summary

- The enrichment ability in China is good enough for tonne-scale Ge-76 enrichment.
- HPGe crystal growth is also started. But we have a long way to go;
- CDEX group is getting experience on HPGe detector fabrication, such as PPC, coaxial, BEGe;
- Front-end electronics development is making good progress, both in JFET based and ASIC based;
- CDEX-10X is under design and test, for both good energy resolution and low background.

Thank You!