The DCBA Double Beta Decay experiment

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$\beta\beta$ experiments in the world

Scintillation/Calorimetry

ionization
COBRA (^{130}Te, ^{116}Cd, etc.)
Majorana(^{76}Ge)
GERDA(^{76}Ge)

scintillation
CANDLES(^{48}Ca)
MOON(^{100}Mo)
KamLAND-Zen(^{136}Xe)
SNO+(^{150}Nd)

bolometry
CUORE(^{130}Te)

Ionization
+scintillation
EXO(^{136}Xe)
NEXT(^{136}Xe)

Combination

NEMO3 (^{100}Mo, ^{82}Se, ^{150}Nd, etc.)
Super NEMO (^{82}Se, ^{150}Nd, etc.)

Tracking (momentum reco.)

DCBA (^{100}Mo, ^{150}Nd, etc.)

(Dis-)Advantages of Tracking method

Advantages:

- Insensitive to the neutral background(e.g. γ-ray)
- More information than other methods:
  - Full 4-momentum and charges of two β-rays
  - Decay vertex position

↳

- Good background rejection:
- More information (E-spectrum of single β, angular correlation) to constrain New Physics beyond the SM (if $0\nu\beta\beta$ observed)

Disadvantage:

For better resolution:
Need to have ***less material*** inside of the tracking volume

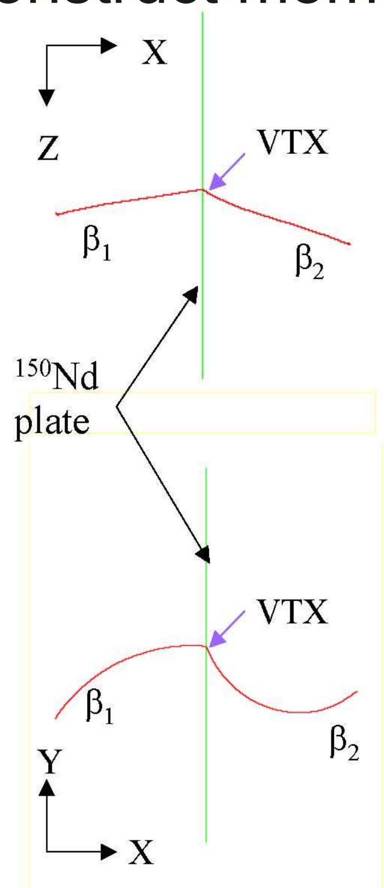
⇕

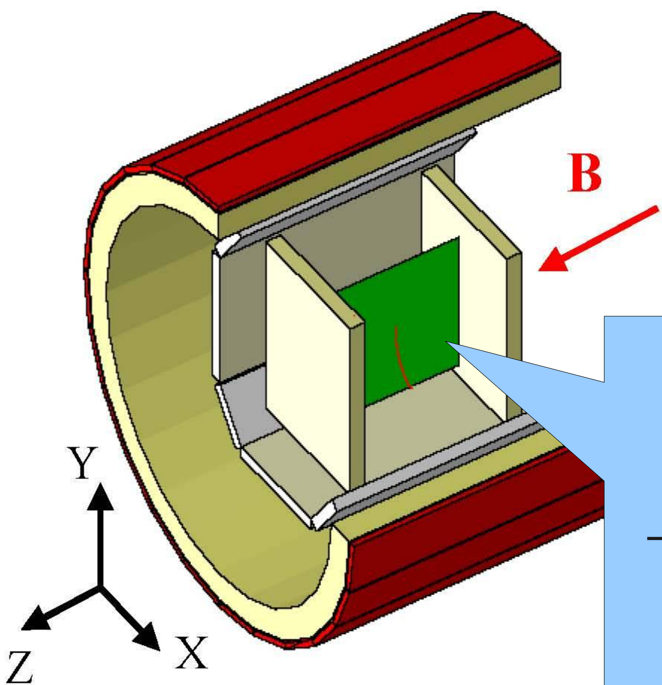
For better statistics:
Need to have ***more source*** inside of the tracking volume

↳ hard to increase source weight

DCBA: method

- have source plate(s) inside of the tracking volume
  Source plate: ^{100}Mo (^{150}Nd in future)
- emitted two electrons make helical trajectories inside of the tracking volume
- reconstruct momenta of two electrons





Source plate is put parallel the the B-field
→ electrons having large angle to the source plate, travel across the B-field

DCBA: track reconstruction method

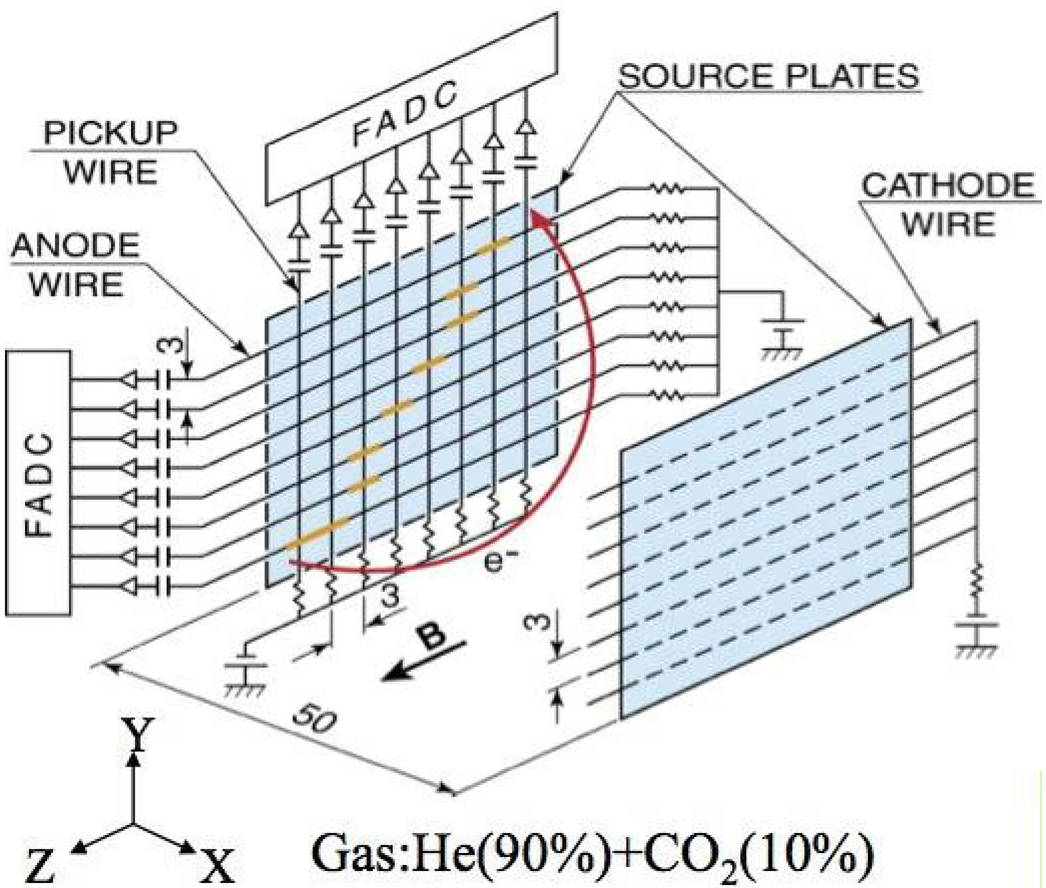
Reconstruction of position information
- X: drift time
- Y: hit position of the anode wire
- Z: hit position of the pickup wire

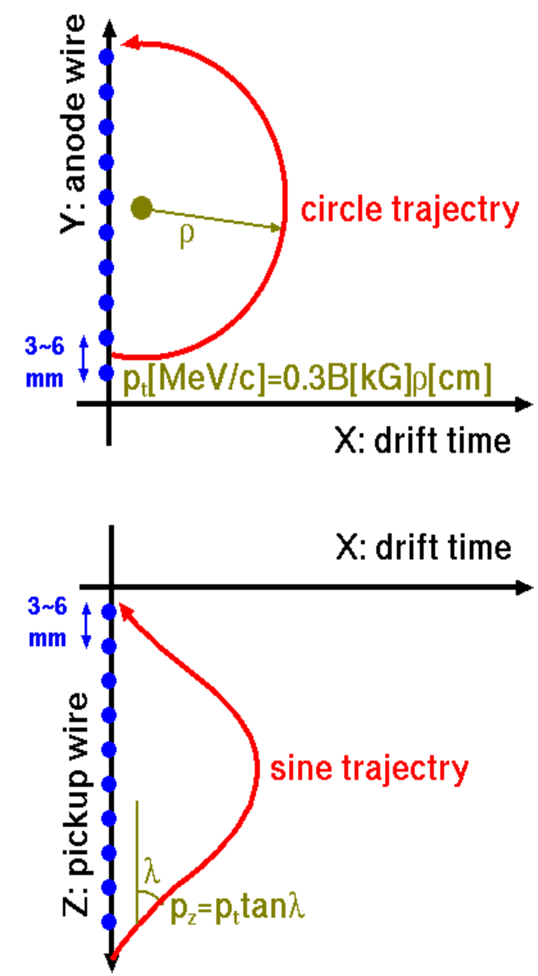
Kinetic energy

$T=\sqrt{p_t^2+p_z^2+m_e^2}-m_e$

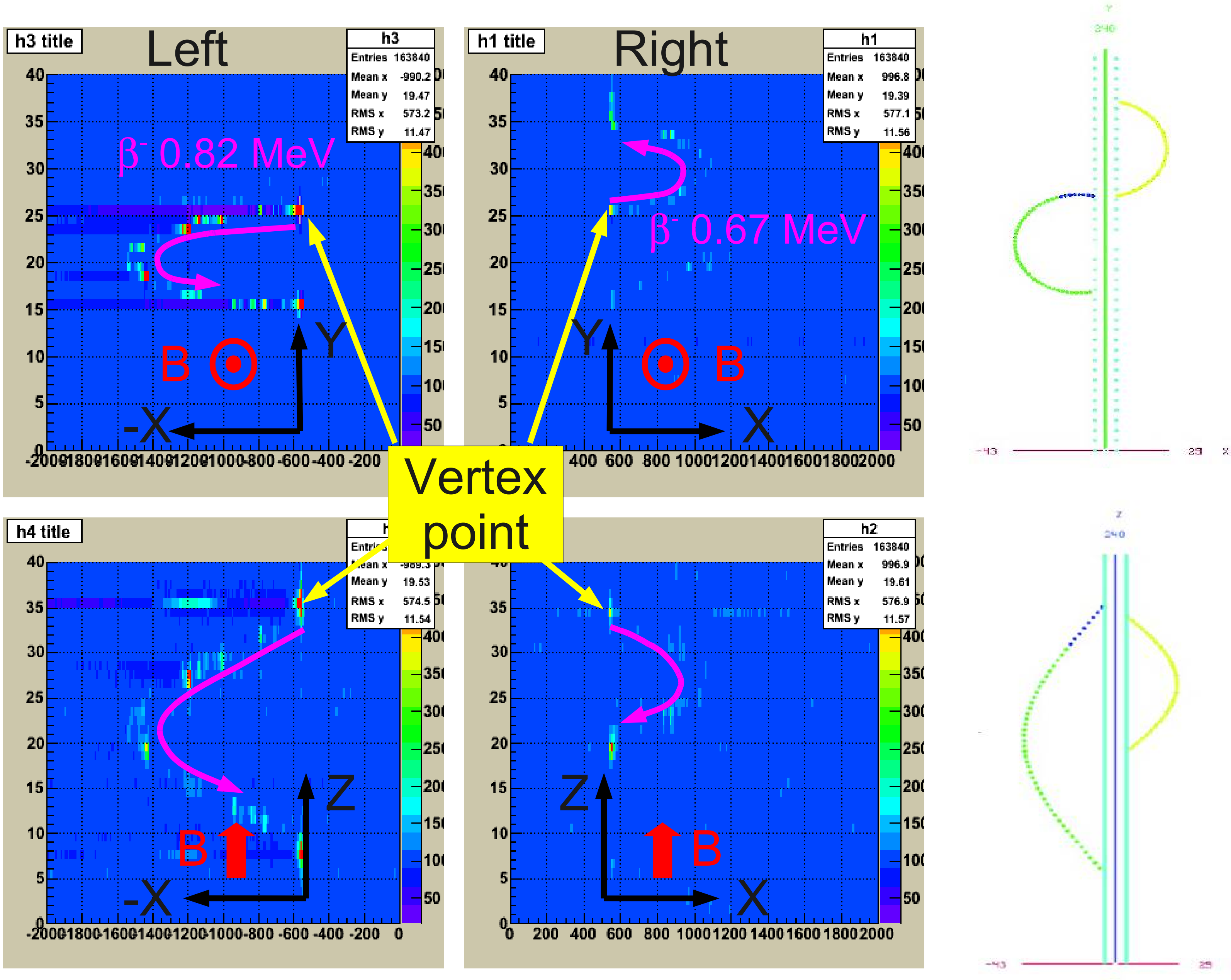
$= \sqrt{(0.3B\rho)^2(1+\tan^2\lambda)+m_e^2}-m_e$

$= \sqrt{(0.3B\rho)^2/\cos^2\lambda+m_e^2}-m_e$



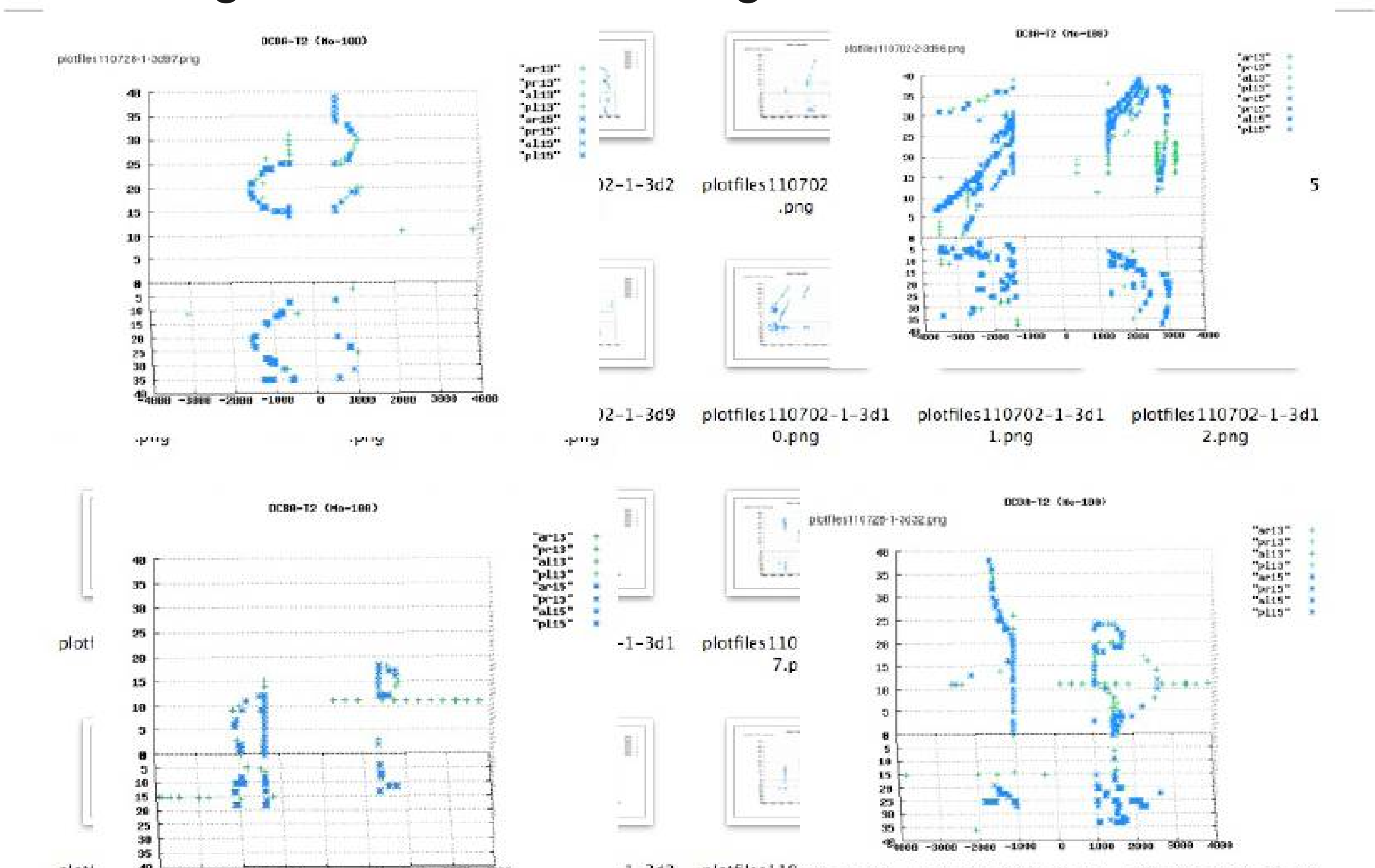


Display of ββ candidate



Event displays

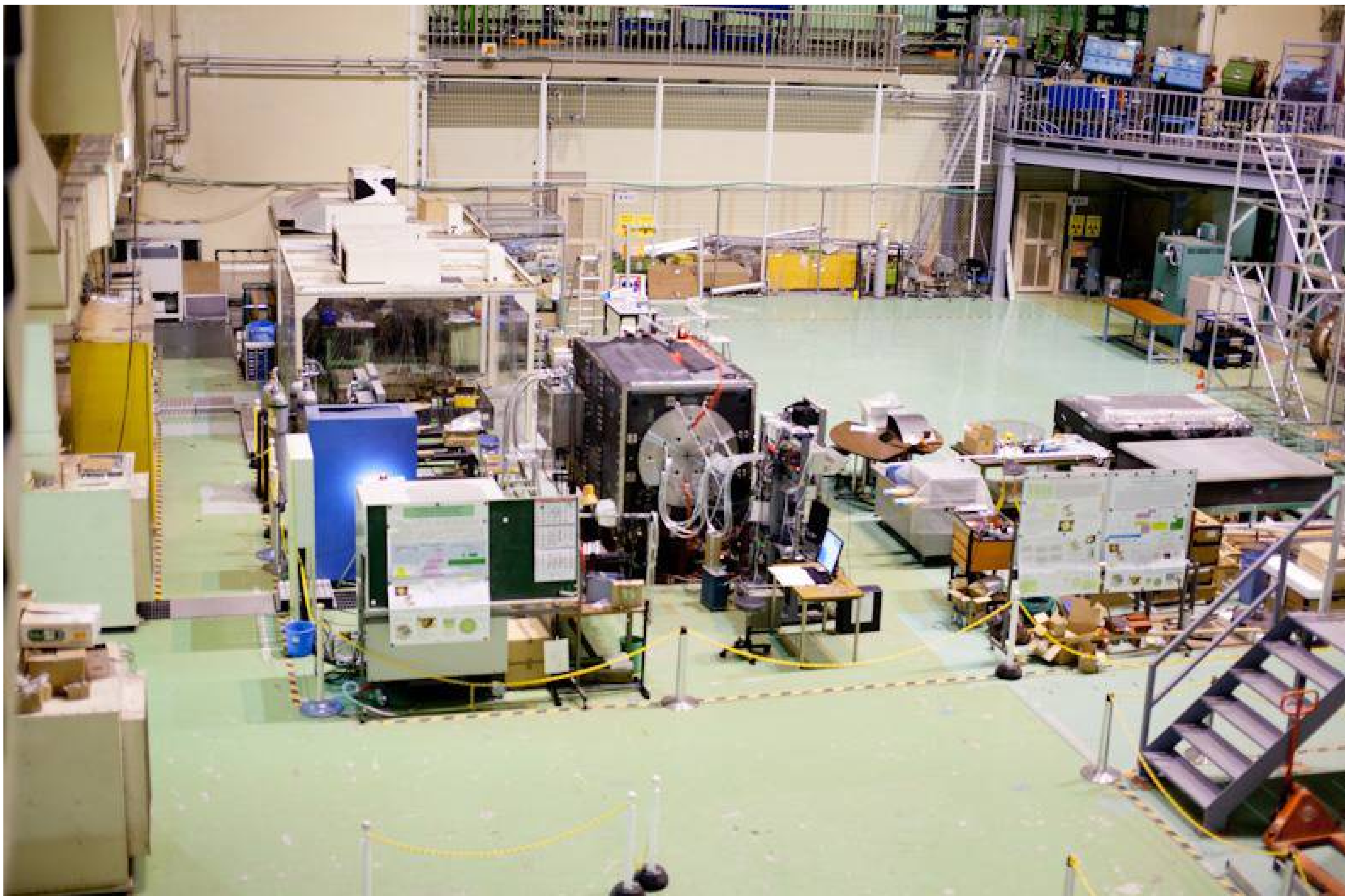
Signal candidate (left-top) and backgrounds(others)
#signal candidate/#background ~ 1/10000



DCBA can separate signals and backgrounds
event-by-event by looking at their hit pattern

DCBA experiment

DCBA experiment is performed at Fuji-experimental hall @ KEK



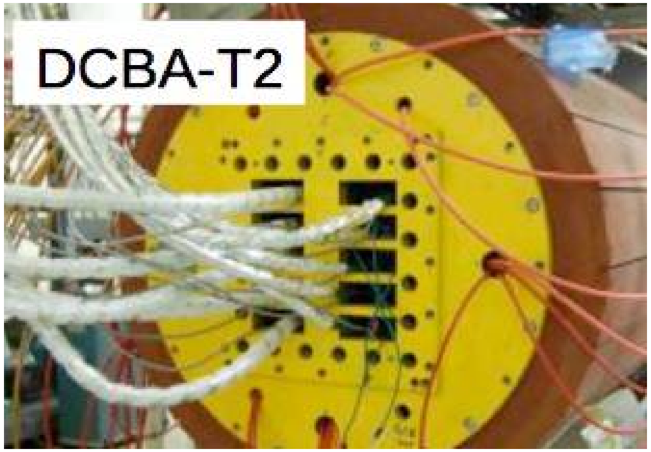
DCBA: history and future plan

2005 DCBA

- charge dividing
- 6 mm pitch wires (xy + xz)

2007 DCBA-T2

- ^{100}Mo source (natural Mo 30g)
- 0.6 - 0.8 kG magnetic field
- Normal conducting magnet: 9h/day operation (Mon.-Fri)

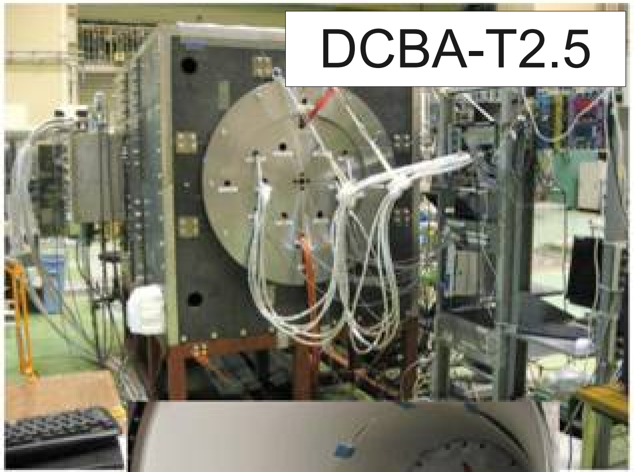


2011 DCBA-T2.5

now

- 6 mm pitch wires (xy + xz)
- ^{100}Mo source (natural Mo 30g)
- 0.8 kG magnetic field
- super-conducting magnet:

24h nonstop operation



2013 DCTA-T3

- 3 mm pitch wires (xy + xz)*8
- ^{150}Nd (5.6% in natural Nd_2O_3)
- B=3 kG at the maximum

DCBA-T2 Chamber installed into the DCBA-T3 SC-Magnet

2017 MTD (tentative name)

- ^{82}Se ^{150}Nd(condensed) several 10 kg

DCBA-T2

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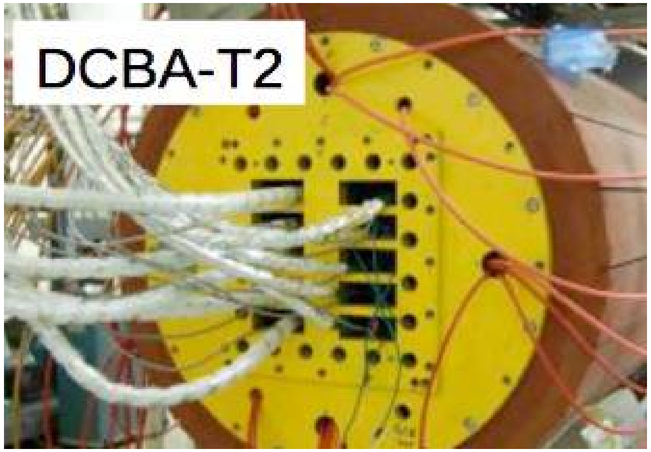
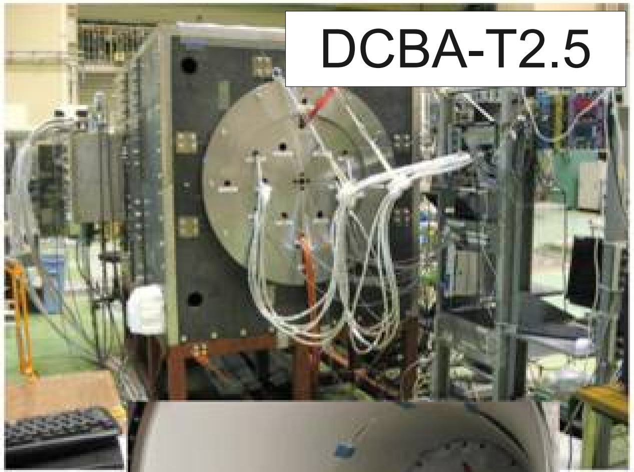
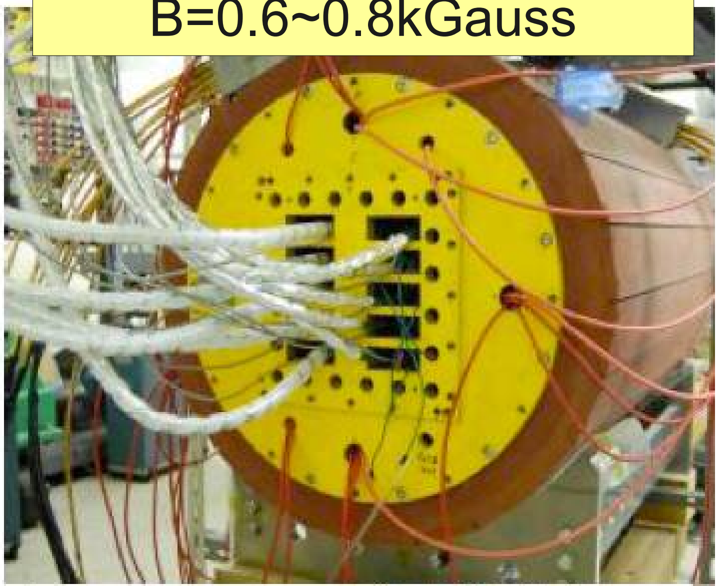


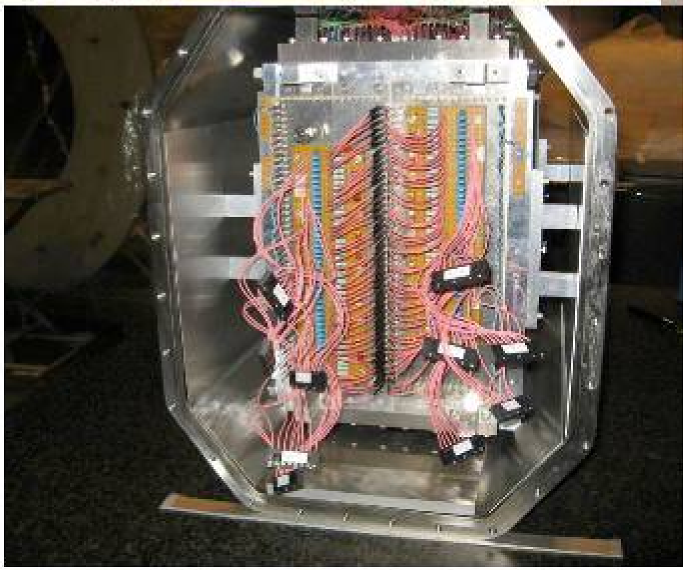


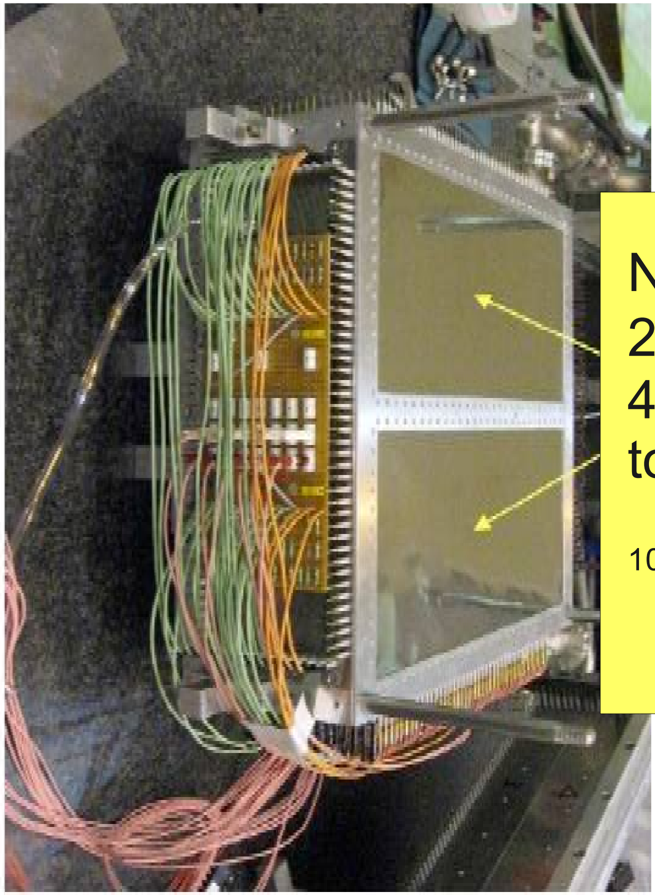
DCBA-T2 Chamber installed into the DCBA-T3 SC-Magnet

DCBA-T2: Detector

Normal condcting manget:
B=0.6~0.8kGauss







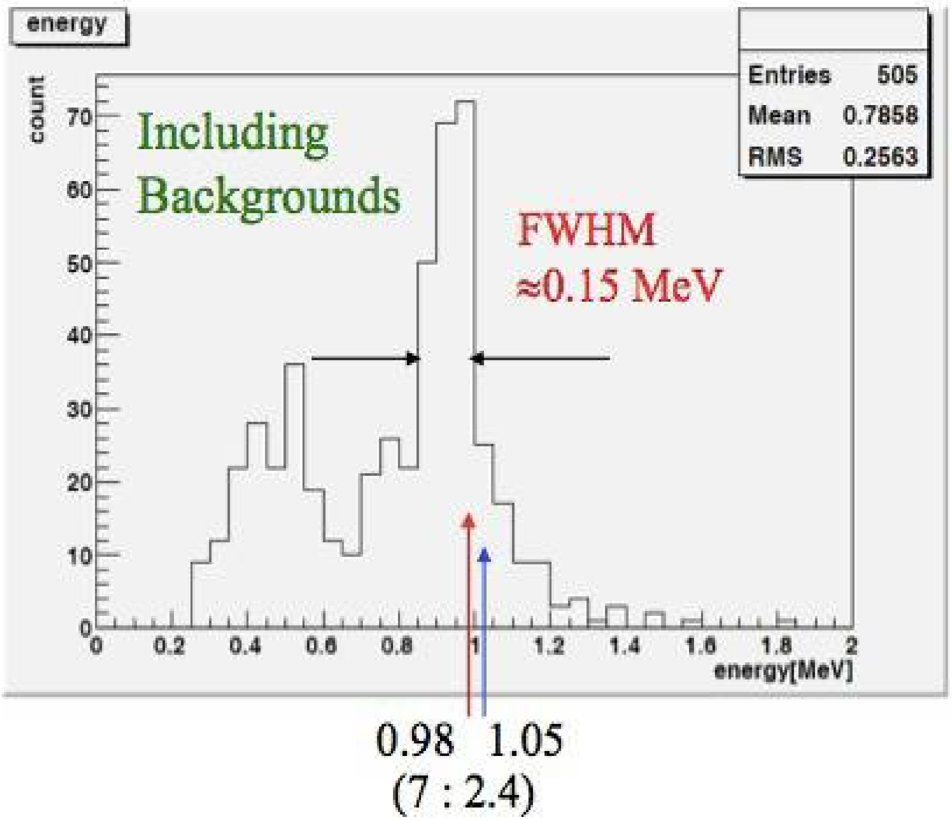
Natural Mo source plate
280mm x 130mm x 50μm
45mg/cm^2
total 30g

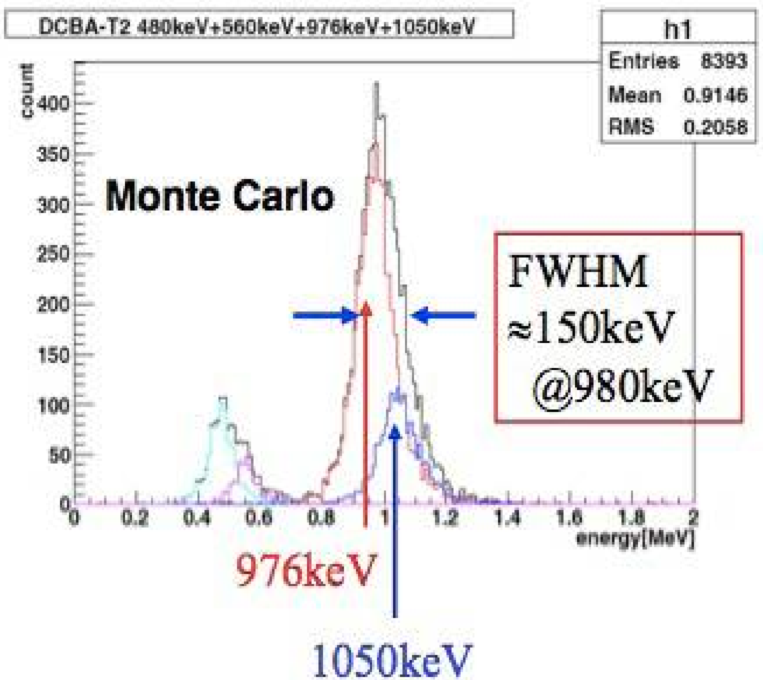
^{100}Mo: 9.6% in the plate
(0.03 mol)

Energy resolution of DCBA-T2

Electron energy:
0.48 MeV(1.5%) 0.56 MeV (0.6%),
0.98 MeV(7.0%) 1.05 MeV (2.4%)

Energy spectra of internal conversion electrons from ^{207}Bi





Chamber conditions
$He(90\%)+CO_2(10\%)$ 1atm
B=0.8 kG
Wire pitch=6 mm

Energy resolution: ~0.15 MeV (FWHM)
This result is also valid for DCBA-T2.5

DCBA-T2.5

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- charge dividing
- 6 mm pitch wires (xy + xz)

2007 DCBA-T2

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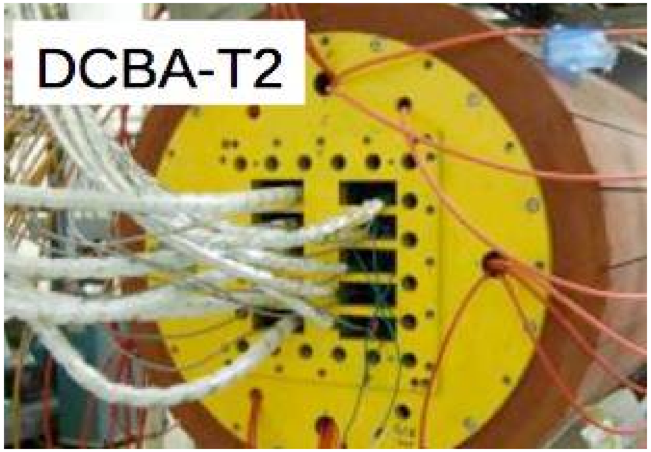
- 0.6 - 0.8 kG magnetic field
- Normal conducting magnet: 9h/day operation (Mon.-Fri)



2011 DCBA-T2.5

now

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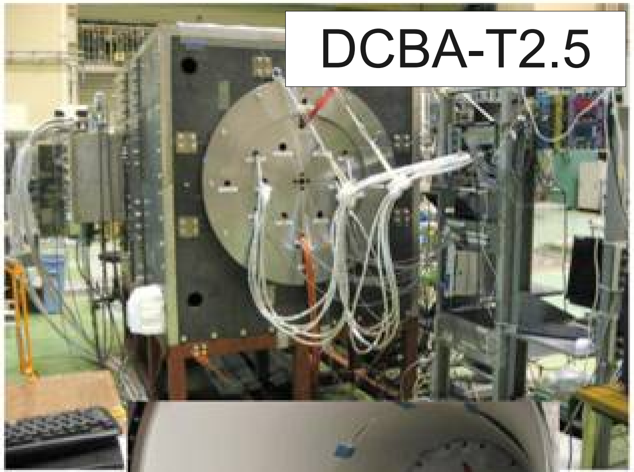
- super-conducting magnet:

24h nonstop operation



2013 DCTA-T3

- 3 mm pitch wires (xy + xz)*8
- ^{150}Nd (5.6% in natural Nd_2O_3)
- B=3 kG at the maximum

DCBA-T2 Chamber installed into the DCBA-T3 SC-Magnet

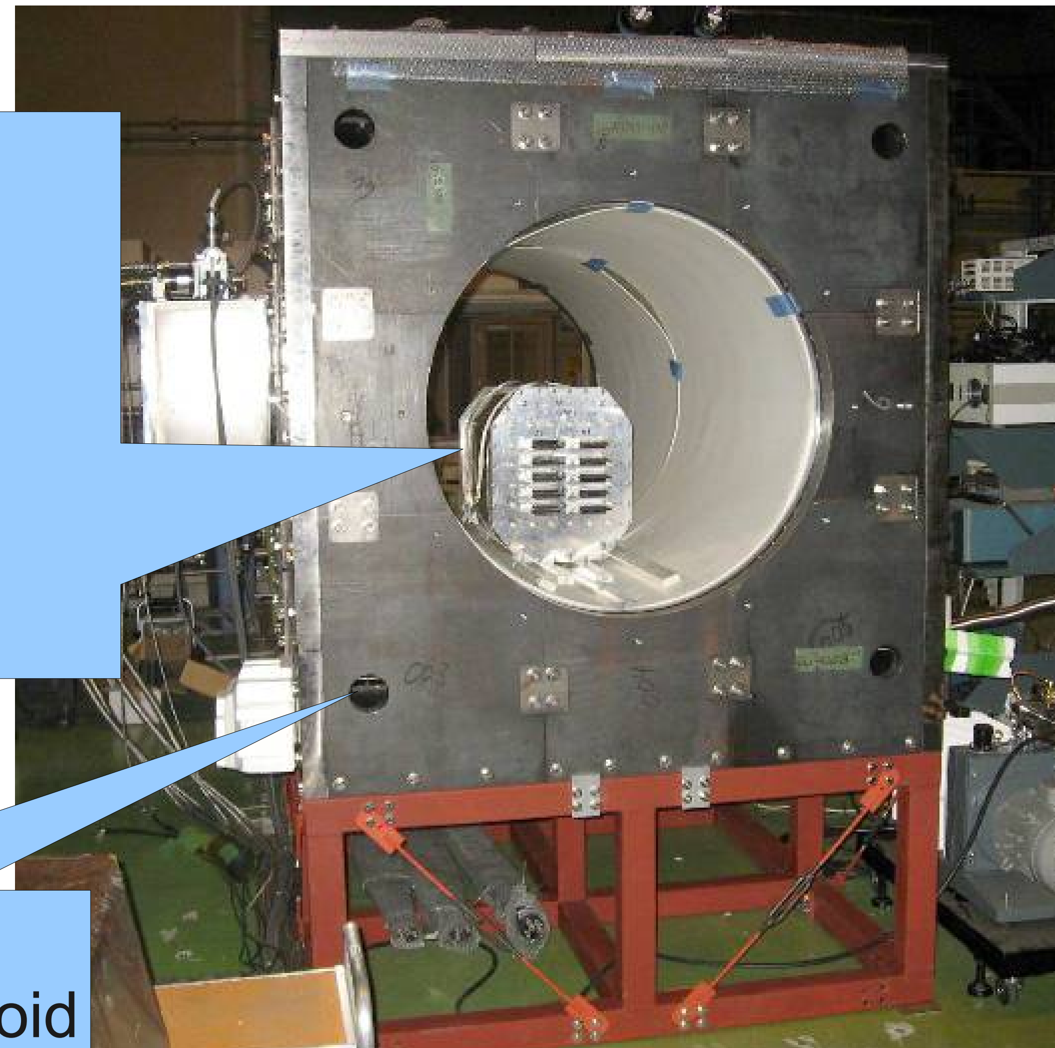
2017 MTD (tentative name)

- ^{82}Se ^{150}Nd(condensed) several 10 kg

DCBA-T2.5

DCBA-T2 chamber is in the DCBA-T3 magnet

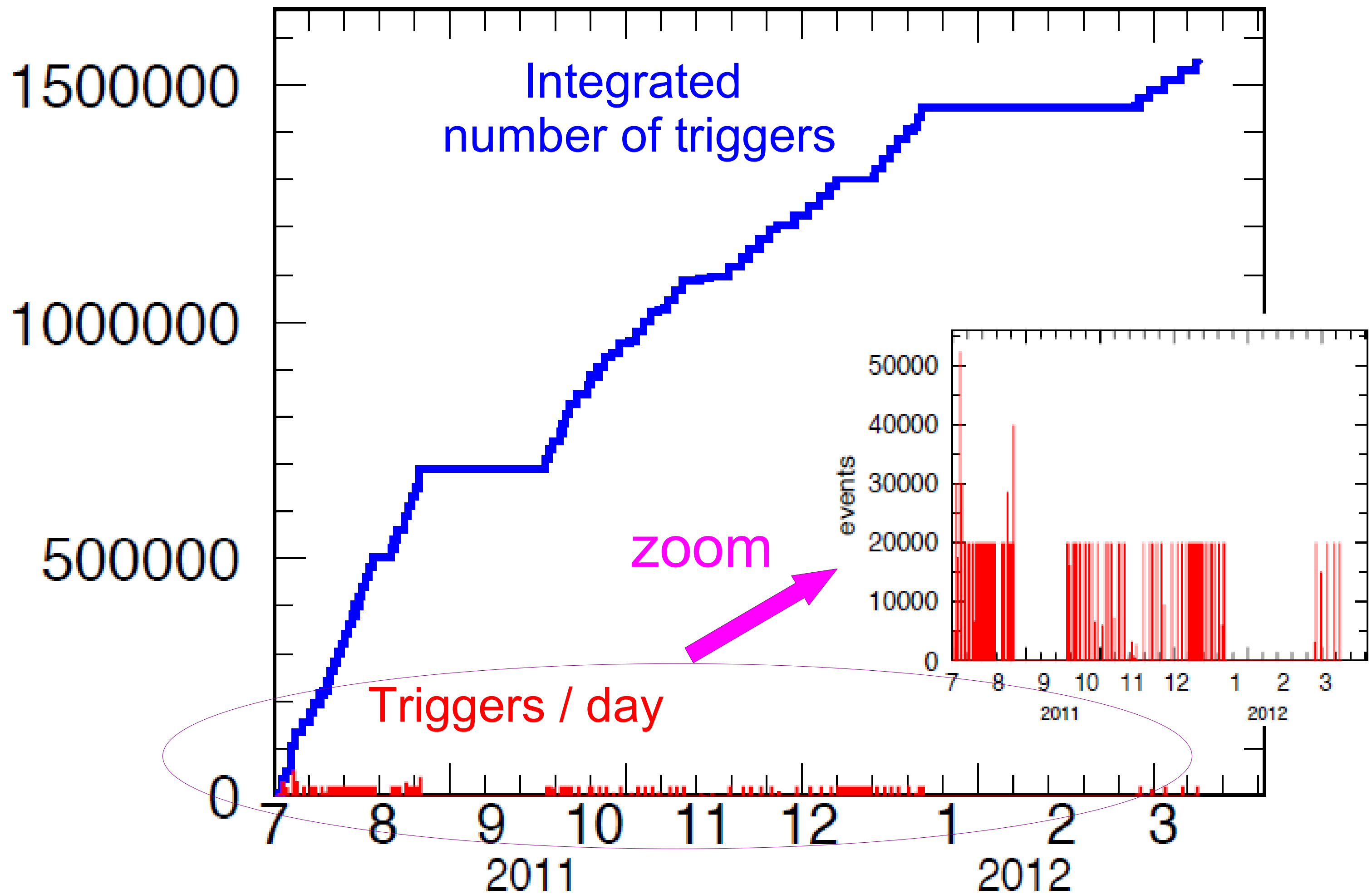
DCBA T2 Chamber



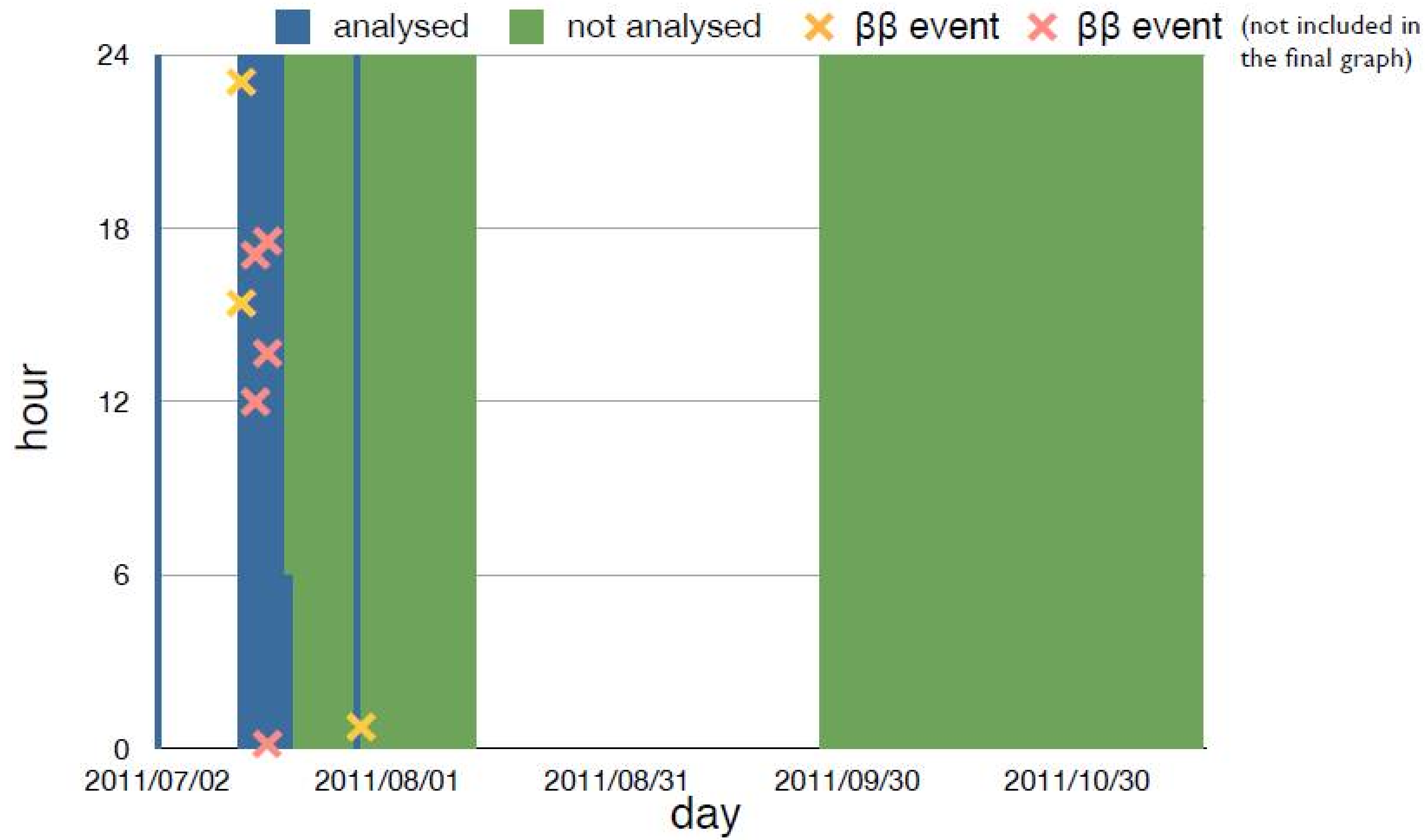
DCBA-T3 Magnet:
Super-Conducting solenoid
24 hour operation

DCBA-T2.5 data

Data taking started at July, 2011
Stably taking data (plot is up to Mar. but taking data after Mar.)

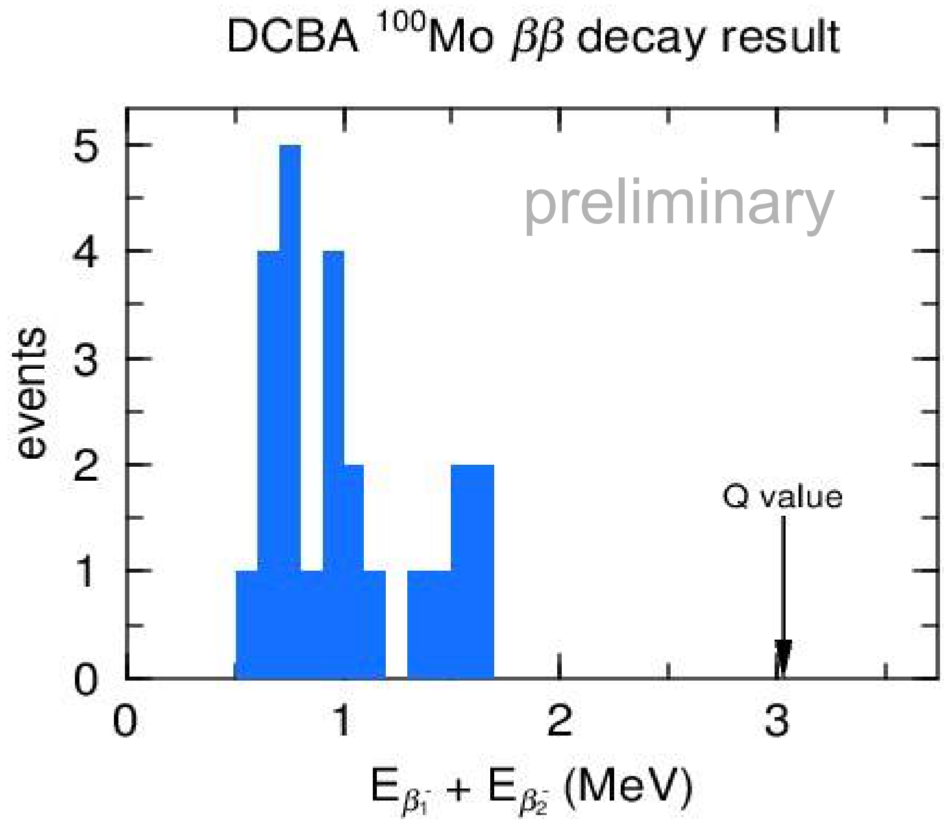


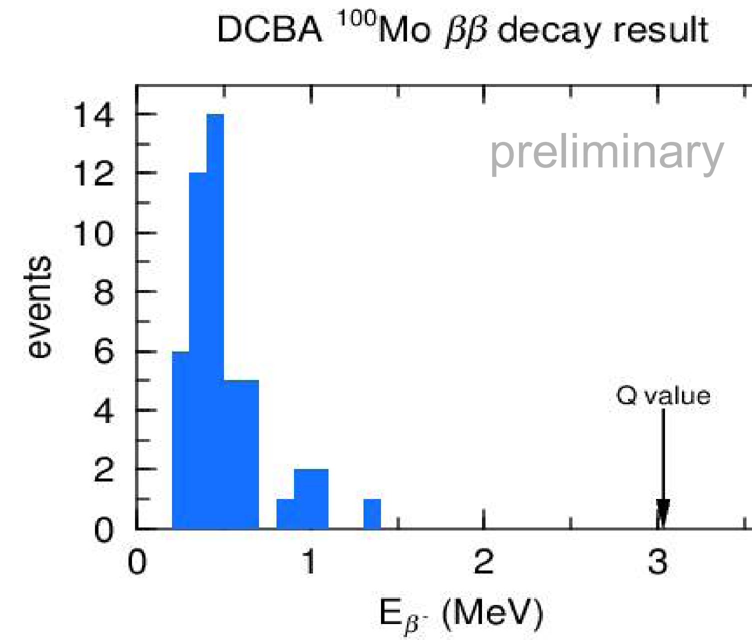
DCBA-T2.5 analyzed events

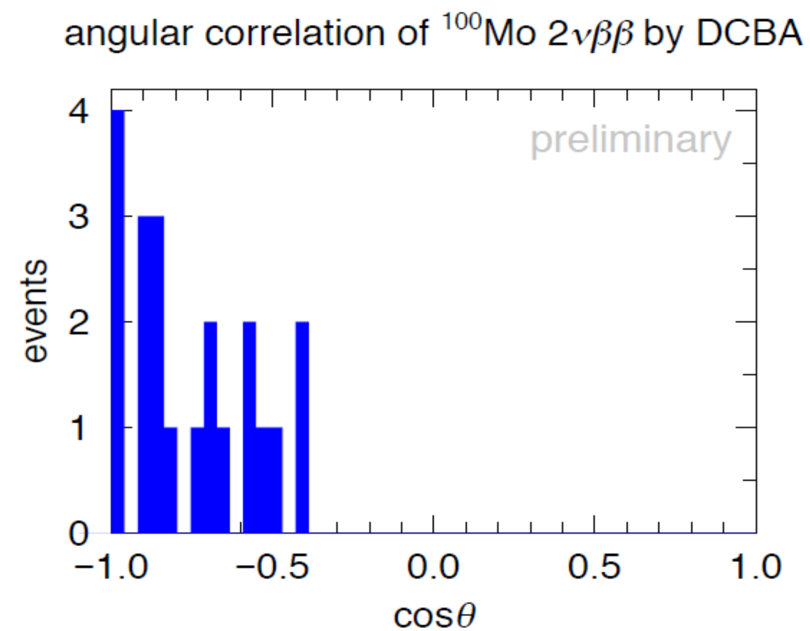


- about 1 signal candidate / 1 day running
- Most of data is not analyzed yet, stay tuned

DCBA-T2+T2.5 result







Three distributions are measured:
- Total energy($E_{\beta1}$+$E_{\beta2}$) distribution
- Single β energy ($E_{\beta1\&\beta2}$) distribution
- angular correlation b/w two βs

(Only a part of T2.5 data is included)

Toward DCBA-T3

2005 DCBA

- charge dividing
- 6 mm pitch wires (xy + xz)

2007 DCBA-T2

- ^{100}Mo source (natural Mo 30g)
- 0.6 - 0.8 kG magnetic field
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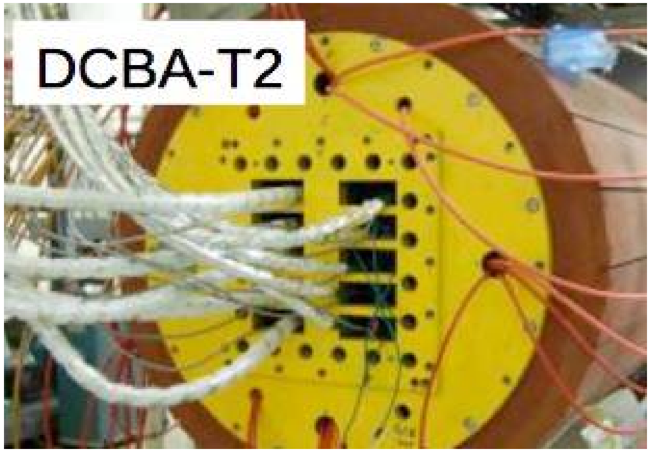

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now

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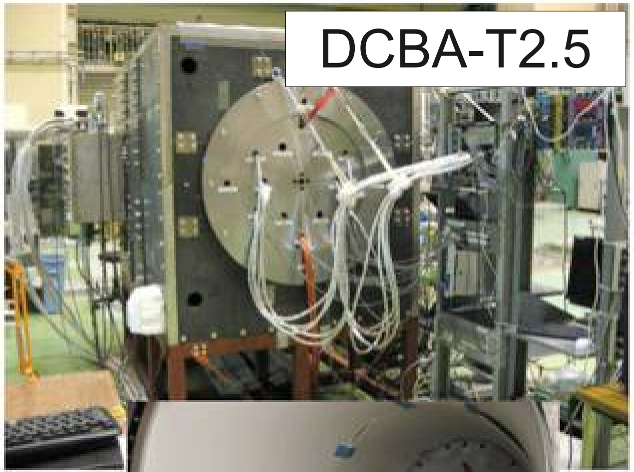
24h nonstop operation



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- 3 mm pitch wires (xy + xz)*8
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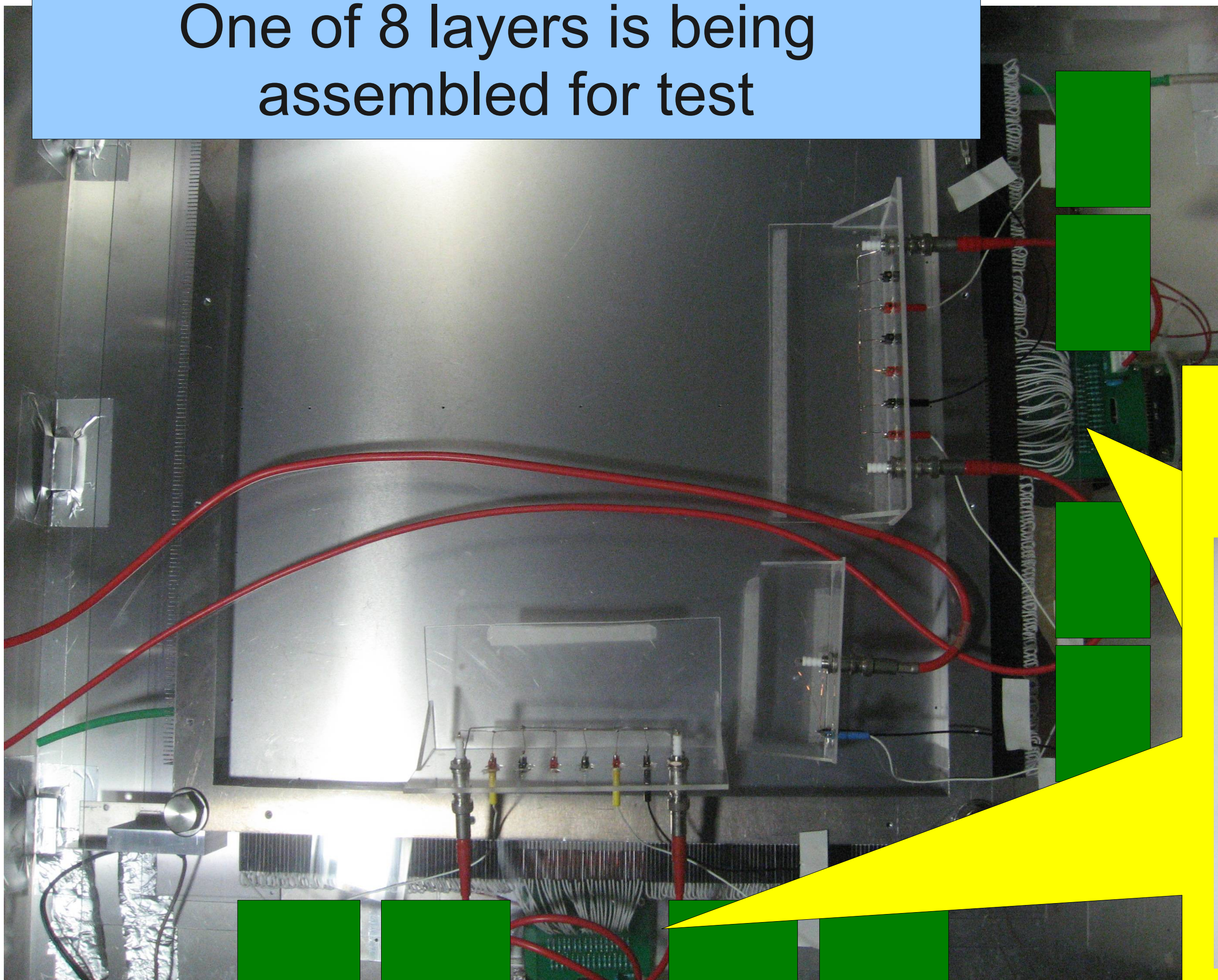
DCBA-T2 Chamber installed into the DCBA-T3 SC-Magnet

2017 MTD (tentative name)

- ^{82}Se ^{150}Nd(condensed) several 10 kg

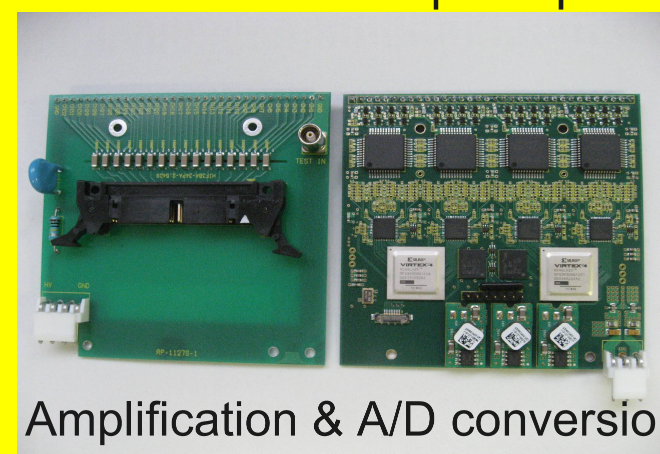
Development of DCBA-T3 Chamber

One of 8 layers is being assembled for test



	T2	T3
# of wires	40	160
Wire pitch	6mm	3mm

32ch Preamp & FADC
- 5 modules for anode
- 5modules for pickup



Amplification & A/D conversion at the chamber side

Expected momentum resolution: <100keV
by fine pitch(6mm→3mm) readout

Next generation experiment: MTD

2005 DCBA

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- 6 mm pitch wires (xy + xz)

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- Normal conducting magnet: 9h/day operation (Mon.-Fri)

2011 DCBA-T2.5

now

- 6 mm pitch wires (xy + xz)
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24h nonstop operation

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(tentative name)

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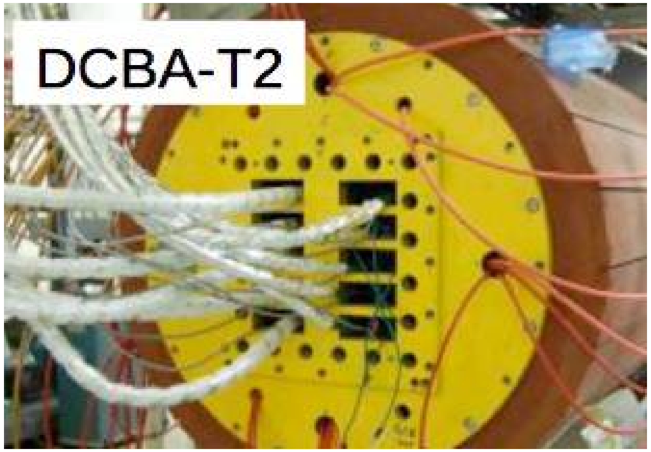
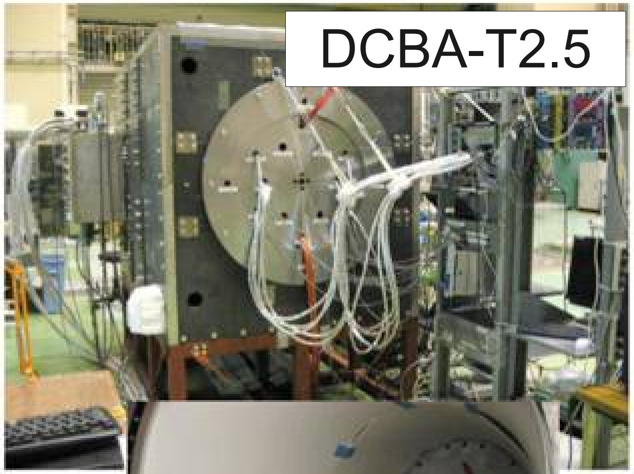


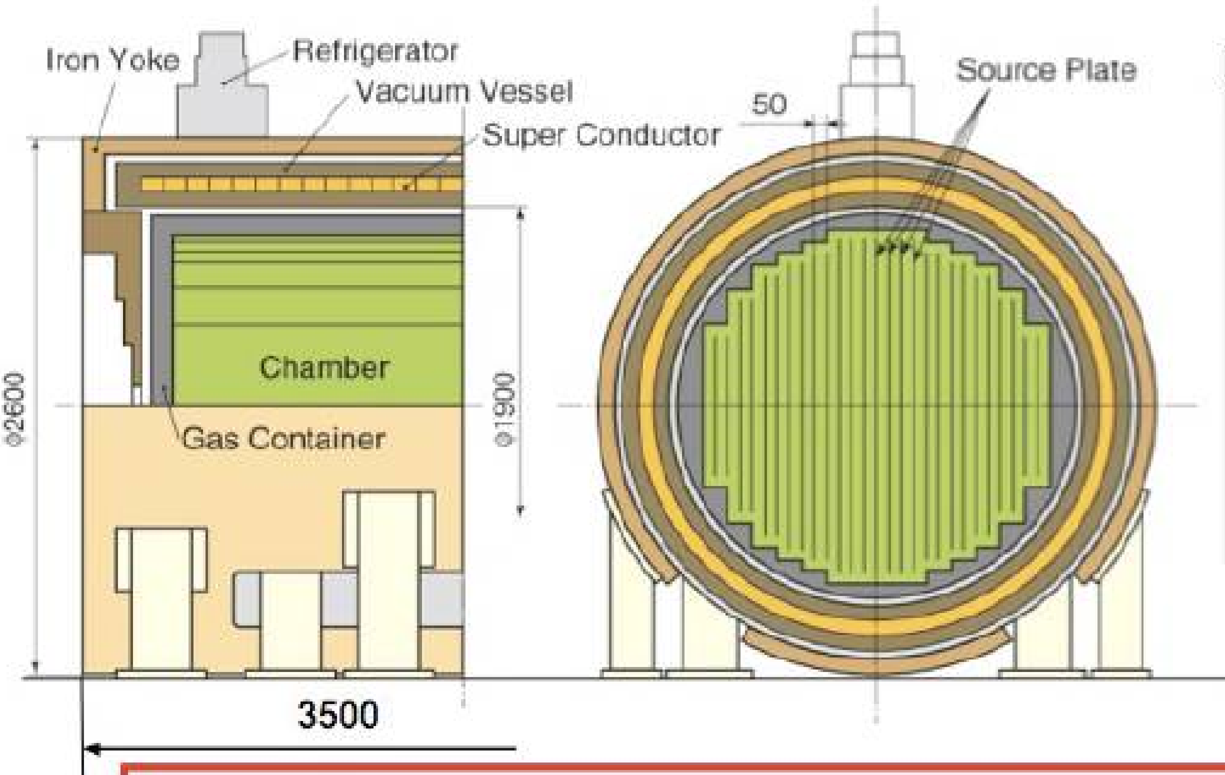


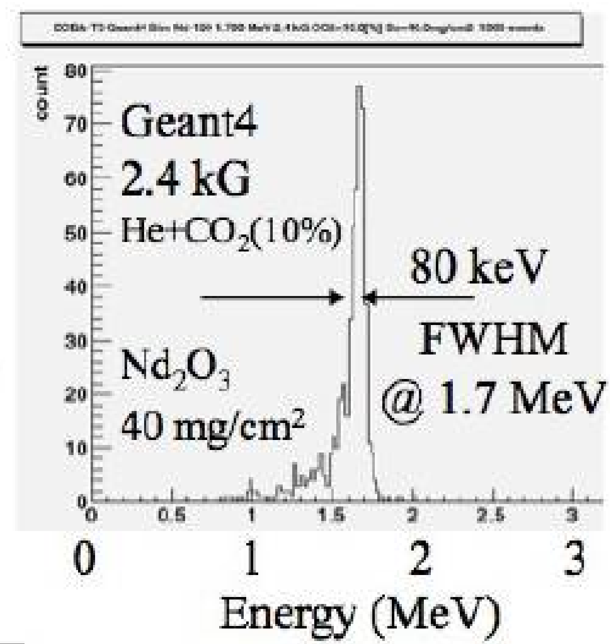
DCBA-T2 Chamber installed into the DCBA-T3 SC-Magnet

Future plan: MTD

Magnetic Tracking Detector (tentative name)

Chamber cell : the same as DCBA-T3, Source plate: 80 m^2/module
Thickness: 40 mg/cm^2, Source weight: 32 kg/module 27 source plates





Expected Energy Resolution $\dfrac{\mathrm{FWHM}(E_{sum}) = \sqrt{2} \times 80\mathrm{keV}}{Q_{\mathrm{Nd\text{-}150}}(3370\mathrm{keV})} \approx 3.4\%$

Summary

DCBA is track-based $\beta\beta$-decay experiment:

- reconstruct full 4-momentum of two β-rays
  more information, less background

DCBA-T2.5 is now running:

- 24 hour operation with Super Conducting solenoid magnet
- 20000 triggers/day, 1 signal candidate/day from ^{100}Mo source

DCBA-T3 is under development:

- Momentum resolution: < 100keV with 3mm pitch
- Eight layers

Future plan: MTD

- Aim to observe $0\nu\beta\beta$ from ^{150}Nd and/or ^{82}Se source
- If $0\nu\beta\beta$ is found, provide information (E-spectrum of single β, angular correlation b/w two βs) to constrain NP beyond the SM