EUCAS 2017
Geneva 17th - 21st September 2017

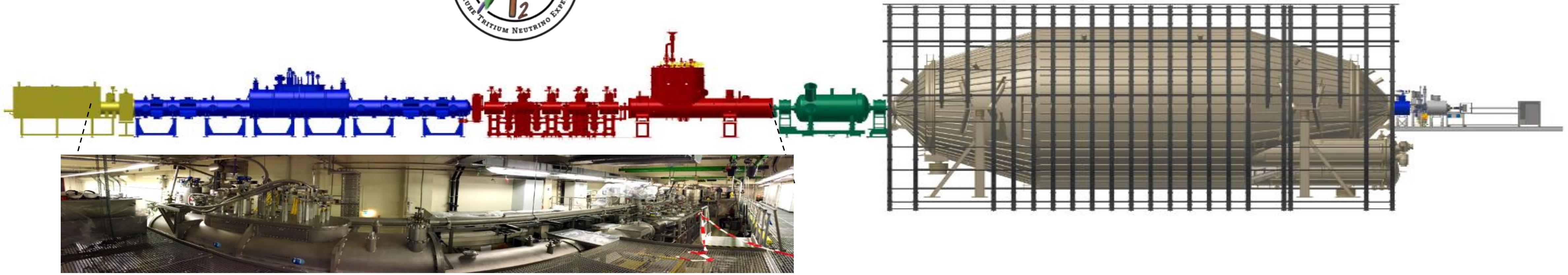
13th European Conference on Applied Superconductivity

First Operation of the Complete KATRIN Superconducting Magnet Chain

4LO2-06, Sept. 21, 2017

Woosik Gil, Institut für Kernphysik (IKP), KIT

for the KATRIN Collaboration



Outline

- Part I: Introduction to KATRIN
  - Karlsruhe Tritium Neutrino Experiment (KATRIN)
  - Measurement principle
  - Chain of the complete KATRIN SC magnets
- Part II: First operation results of the SC magnet chain for “First-Light-Plus” measurement campaign
  - Quench Detection
  - Beam alignment
  - B-field stability
- Summary and Outlook

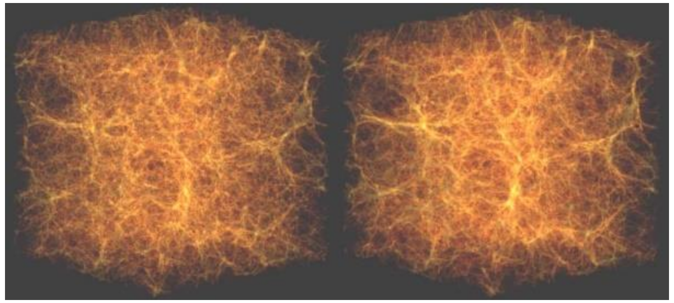
Outline

- Part I: Introduction to KATRIN
  - Karlsruhe Tritium Neutrino Experiment (KATRIN)
  - Measurement principle
  - Chain of the complete KATRIN SC magnets
- Part II: First operation results of the SC magnet chain for “First-Light-Plus” measurement campaign
  - Quench Detection
  - Beam alignment
  - B-field stability
- Summary and Outlook

Karlsruhe Tritium Neutrino experiment (KATRIN)

Neutrino (ν)–mass?

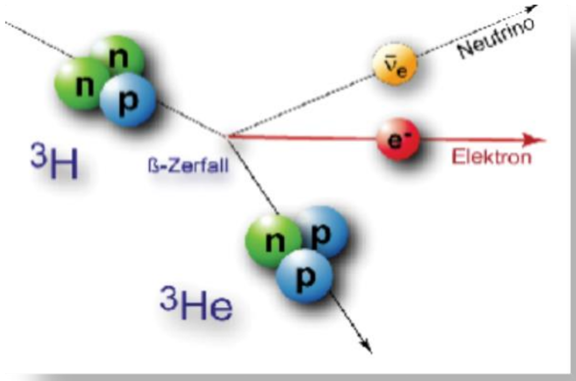
→ Influence on universe structure formation?



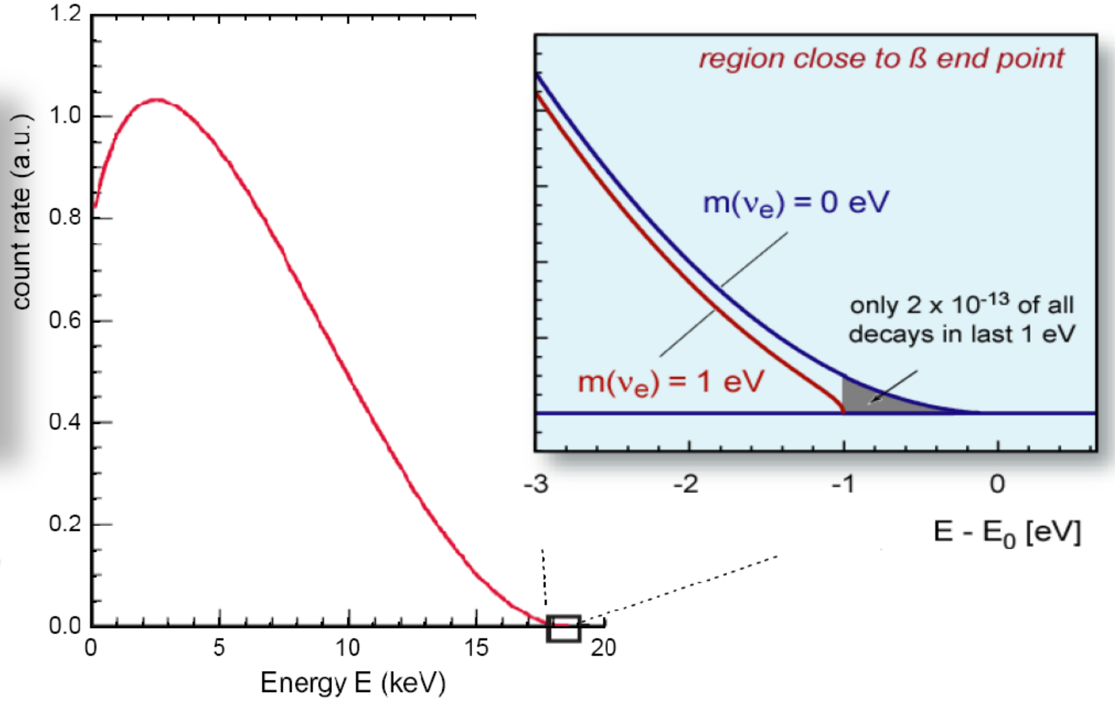
$m(\nu_e) = 0$ 2.3 eV/c^2

→ Absolute ν_e–mass?

→ Model-independent measurement of $m^2(\bar{\nu}_e)$ based on energy-momentum conservation of tritium β-spectrums



Tritium (3H):
E_0 = 18.6 keV, $T_{1/2}$ = 12.3 y



Requirements:

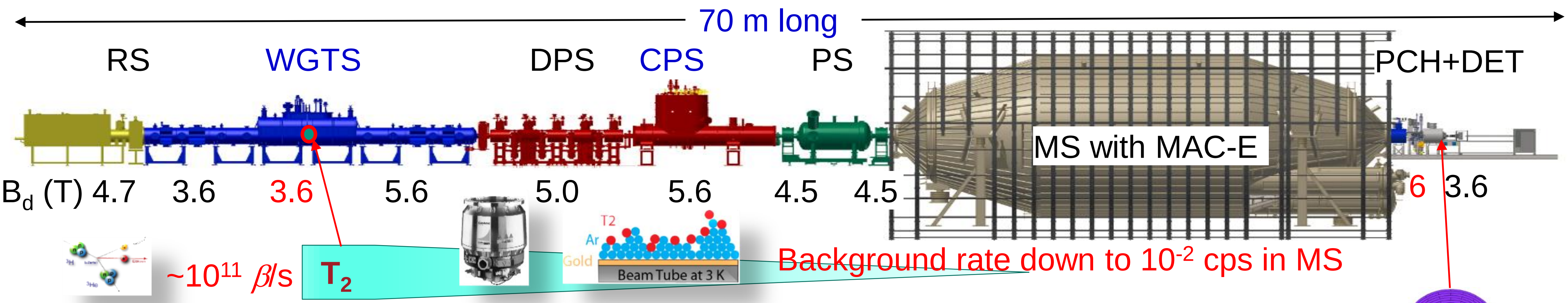
1. High source luminosity
2. High energy resolution
3. Low background rate

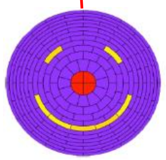
→ 10 times more sensitivity of 0.2 eV/c^2 (C.L.90%)

→ Possibility of 0.35 eV/c^2 in 5σ after 3 years-data-taking

http://www.katrin.kit.edu/ KATRIN Design Report 2004, FZKA 7090

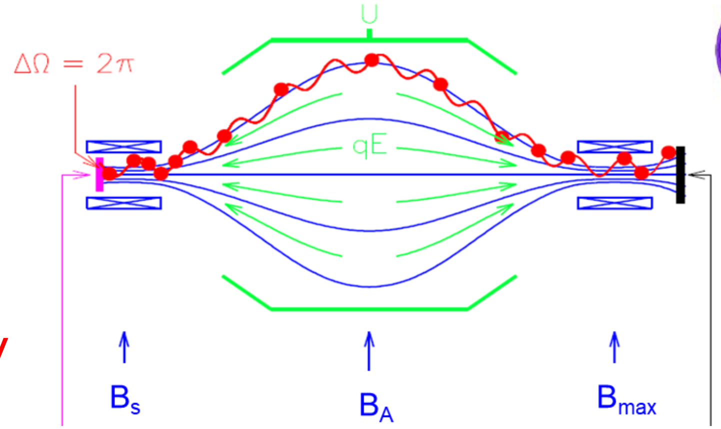
Measurement principle of KATRIN

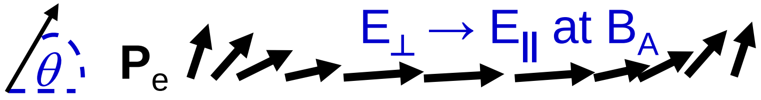




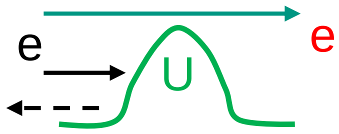
- **M**agnetic **A**diabatic **C**ollimation with **E**lectrostatic (MAC-E*) filter
  - Adiabatic transport: $\mu = \frac{E_\perp}{B} = const.$
  - Electrostatic filter (U) in MS: 18.6 kV
  - Energy resolution: $\Delta E = E_0 \frac{B_A}{B_{max}} = 18.6keV \frac{0.3\ mT}{6\ T} = 0.93$ eV
  - Max. acceptance angle of β:

$$\theta_{max} = \arcsin(\sqrt{B_s/B_{max}})$$





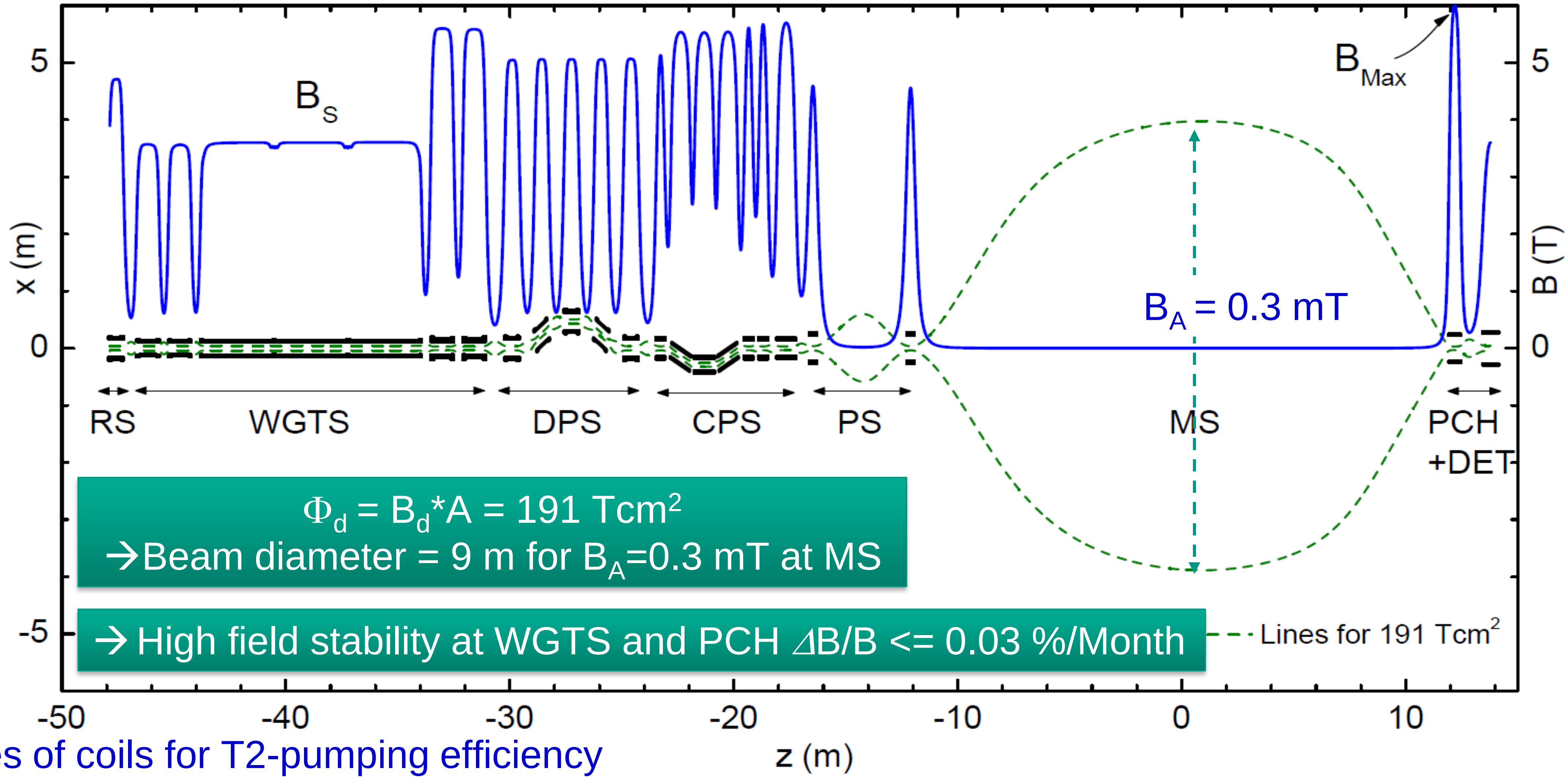
Transmission of β with $E_{||} > U$, $\theta < \theta_{max}$



* Picard et al., 1992

Chain of the KATRIN SC solenoid magnets

- 24 solenoid modules
- 4 dipole coil pairs at the WGTS
- Cu/NbTi

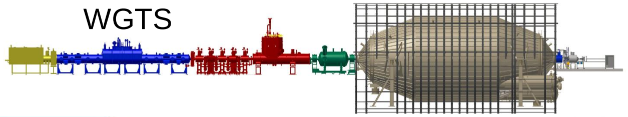


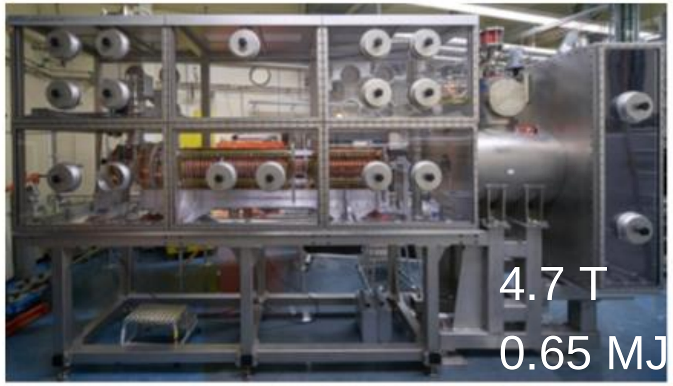
Short distances of coils for T2-pumping efficiency

→ Non-negligible inductive coupling effect on Quench Detection System (QDS)*!

*Gil, IEEE ASC, 2016

Main components of the KATRIN experiment

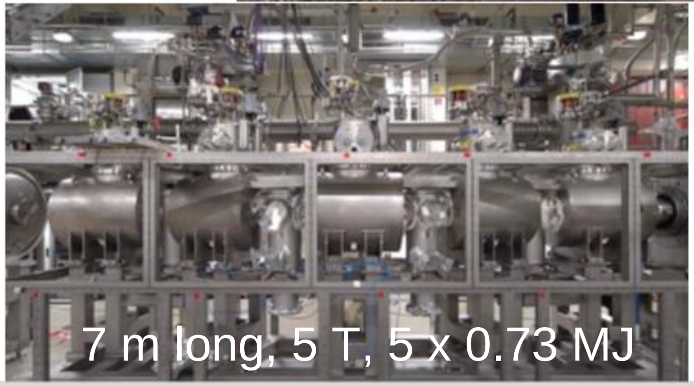




←RS

WGTS→
Sept. 2015

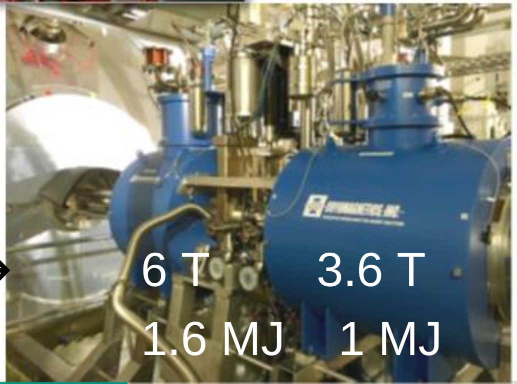
PS→
2004



←DPS

CPS→
July, 2015

PCH+
DET→

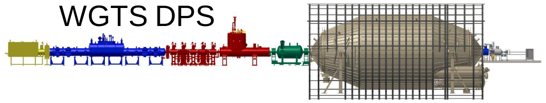


Complete installation at KIT in September, 2016

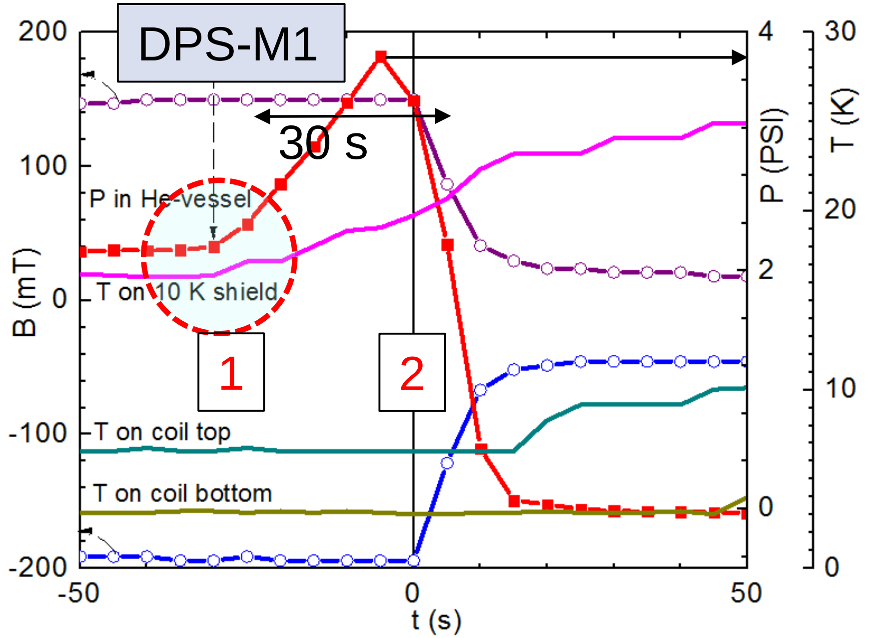
Outline

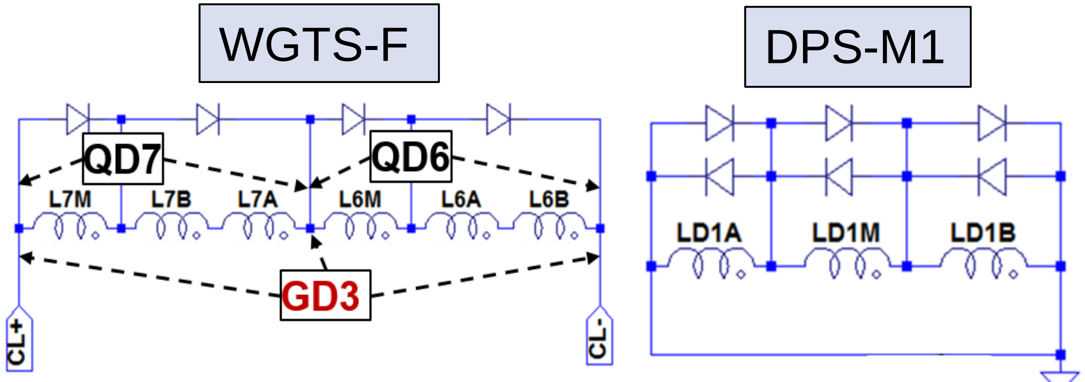
- Part I: Introduction to KATRIN
  - Karlsruhe Tritium Neutrino Experiment (KATRIN)
  - Measurement principle
  - Chain of the KATRIN SC magnets
- Part II: First operation results of the SC magnet chain for “First-Light-Plus” measurement campaign
  - Quench Detection
  - Beam alignment
  - B-field stability
- Summary and Outlook

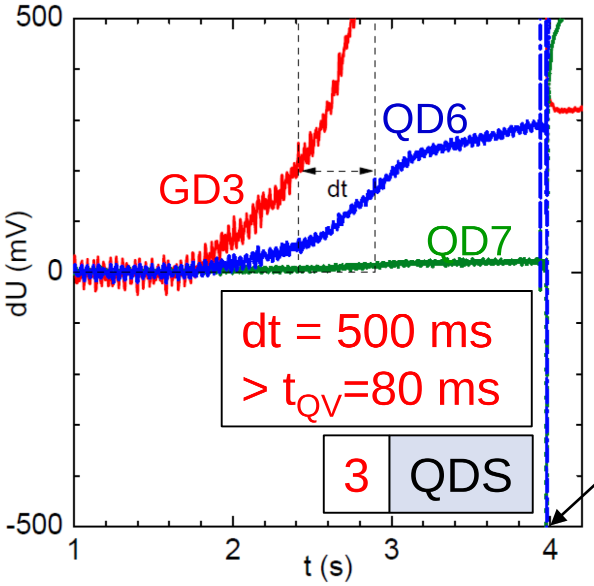
Quench detection by the Magnet Safety System

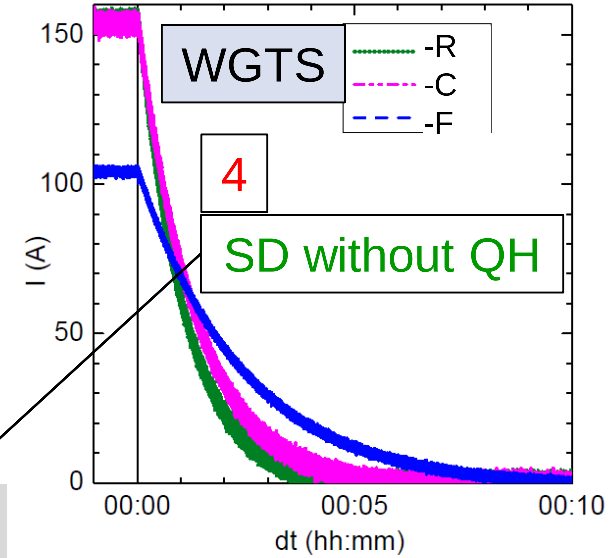


- Quench detection by considering M_{ij} at 50 % of I_D
  - Quench in DPS-M1 during ramping on Oct. 11, '16
  - Successful quench validation by WGTS-MSS (*)
  - Slow discharge (SD) of WGTS without quench
  - Distinct quench detection by MSS of WGTS
    → save of large amount of LHe (2 m^3) and time!









Successful operation of the MSS

*Gil, MT25

"First-Light" on Oct.14, 2016

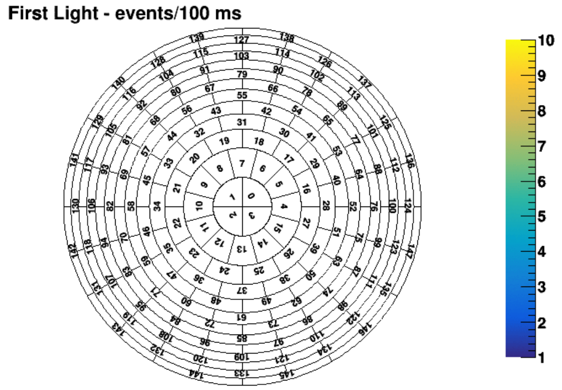
- CERN Courier, Dec. 2016

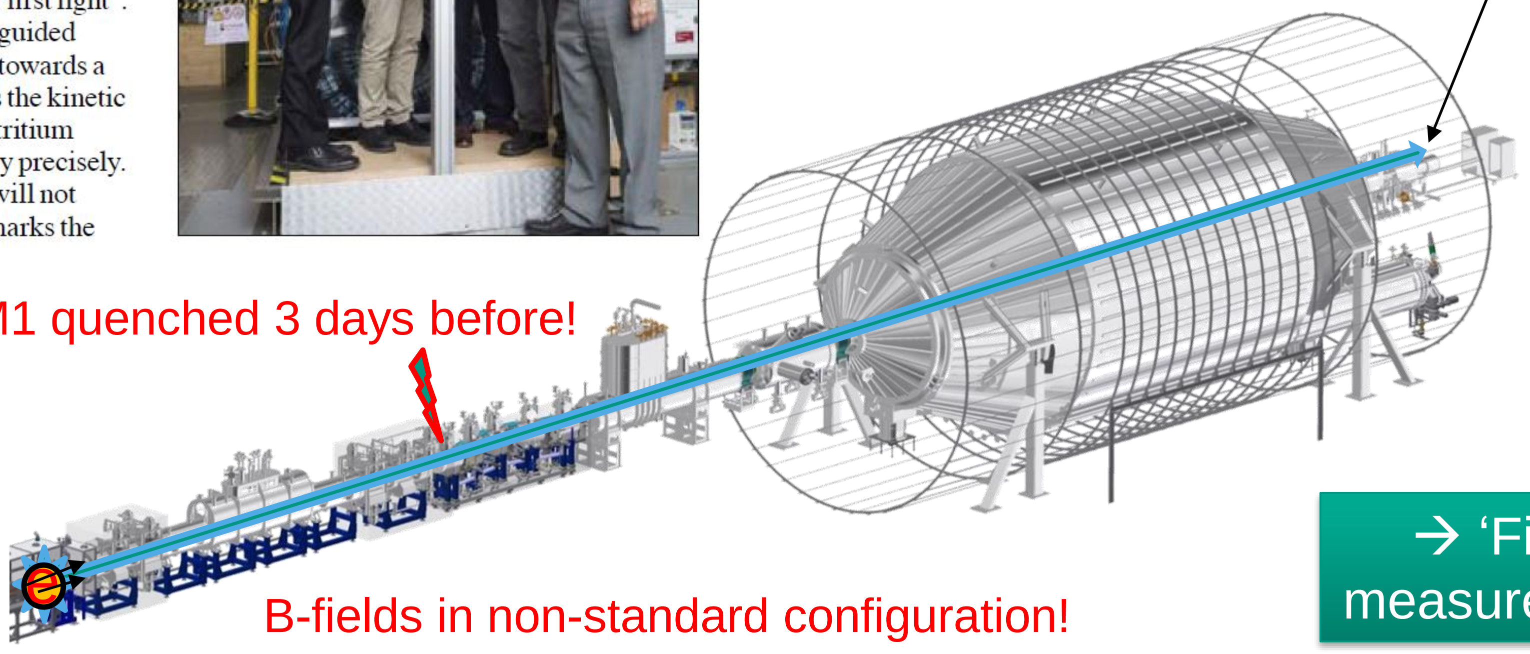

FACILITIES

KATRIN celebrates first beam

Patrick Langer, KIT

On 14 October, the KArlsruhe TRItium Neutrino (KATRIN) experiment, which is presently being assembled at Tritium Laboratory Karlsruhe on the KIT Campus North site, Germany, celebrated "first light". For the first time, electrons were guided through the 70 m-long beamline towards a giant spectrometer, which allows the kinetic energy of the beta electron from tritium beta decays to be determined very precisely. Although actual measurements will not get under way until next year, it marks the





DPS-M1 quenched 3 days before!

Low energetic electron source

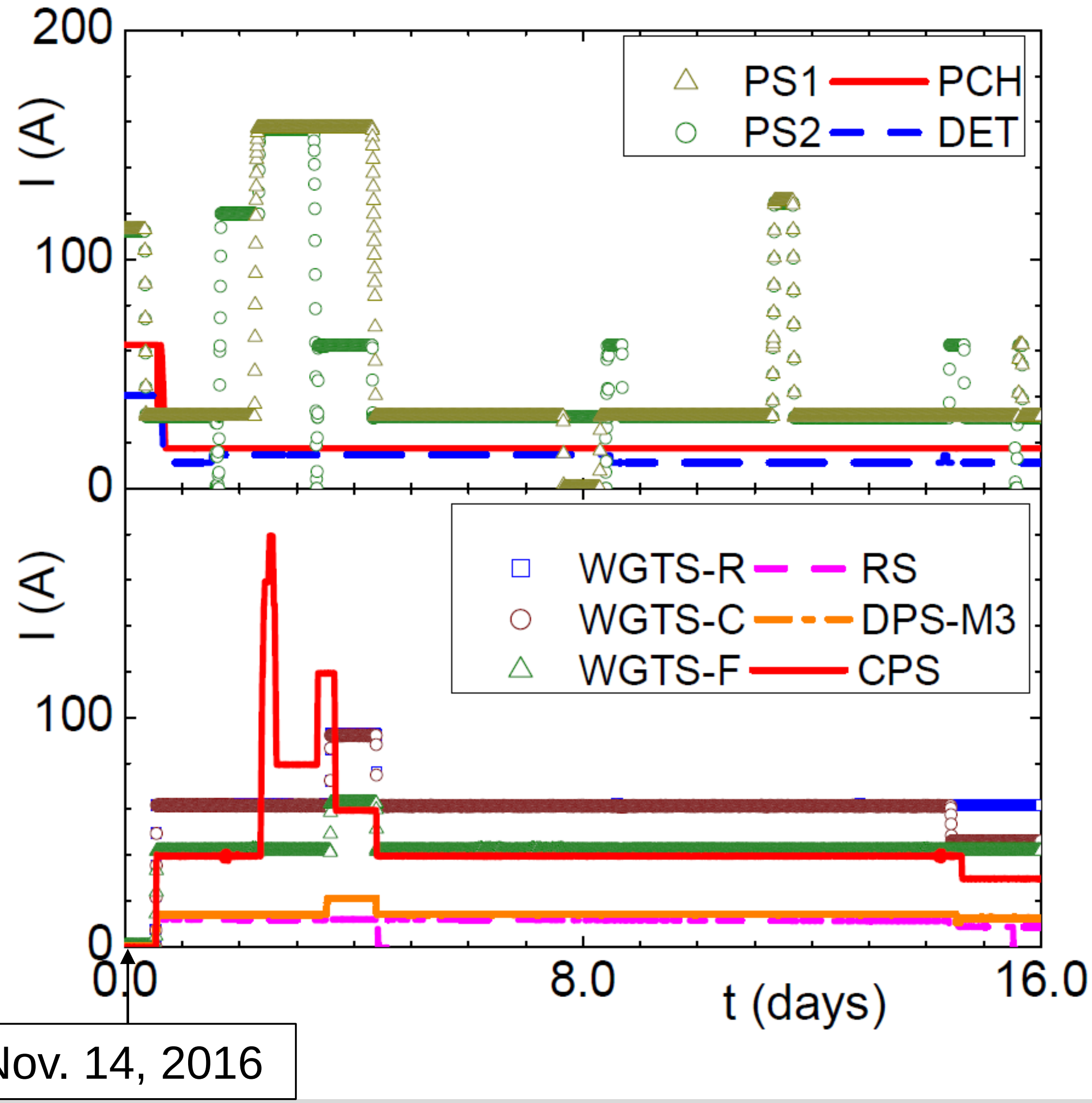
B-fields in non-standard configuration!

→ 'First-Light-Plus' measurement campaign!

Continuous magnet operation for about 2 weeks

- First-Light-Plus
  - Beam alignment check mostly at 20 % of I_D
  - Other tests: electrostatic dipoles for ion-elimination, background signals, etc.

Stable operation for this campaign:
- Cryogenic systems
- Compressors
- Vacuum systems
- Power supplies
- Slow control systems



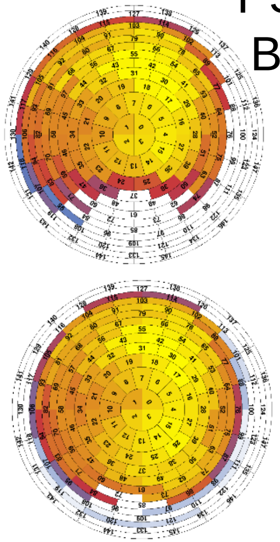
Check of beam alignment

- Full beam illumination on RW

1. Changing magnetic fields sectionwise!
2. Changing electrostatic voltages on electrodes and RW

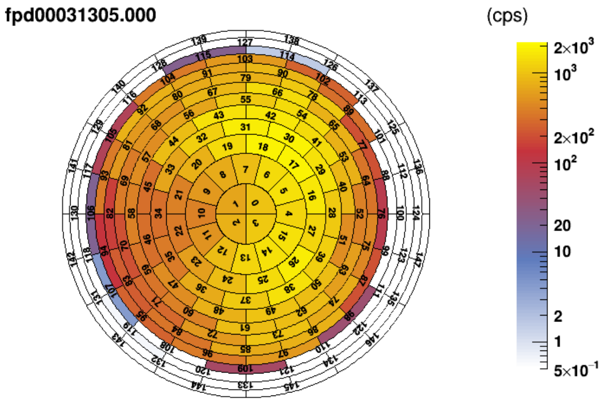
→ No issue for tritium with 18 keV becasue of low static energy (recently verified by Krypton measurement in July, 2017).

PS2:
B = 100%

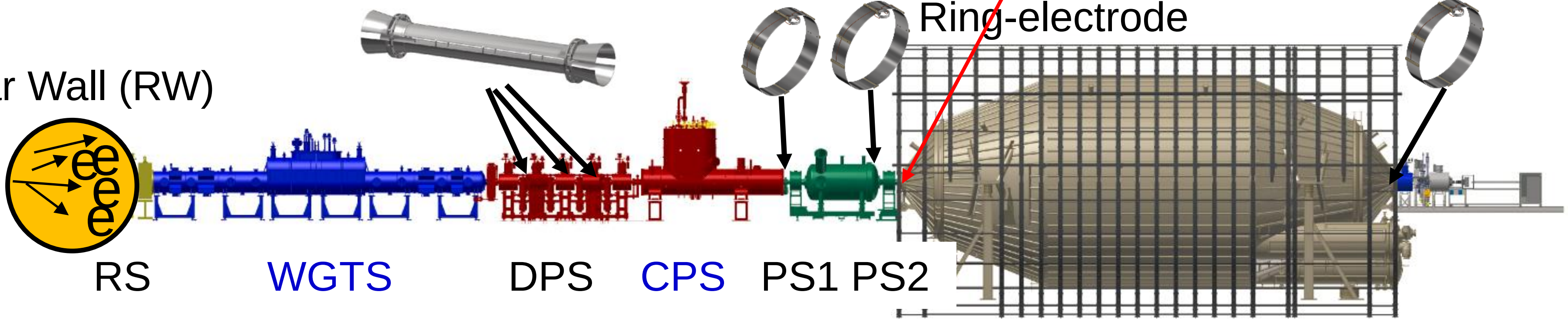


RW: -110 V

Nov. 22, 2016

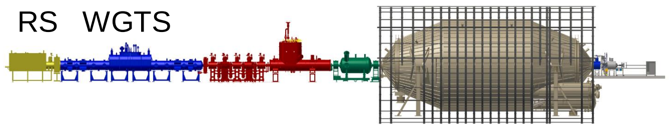


DET: from 25% to 20%

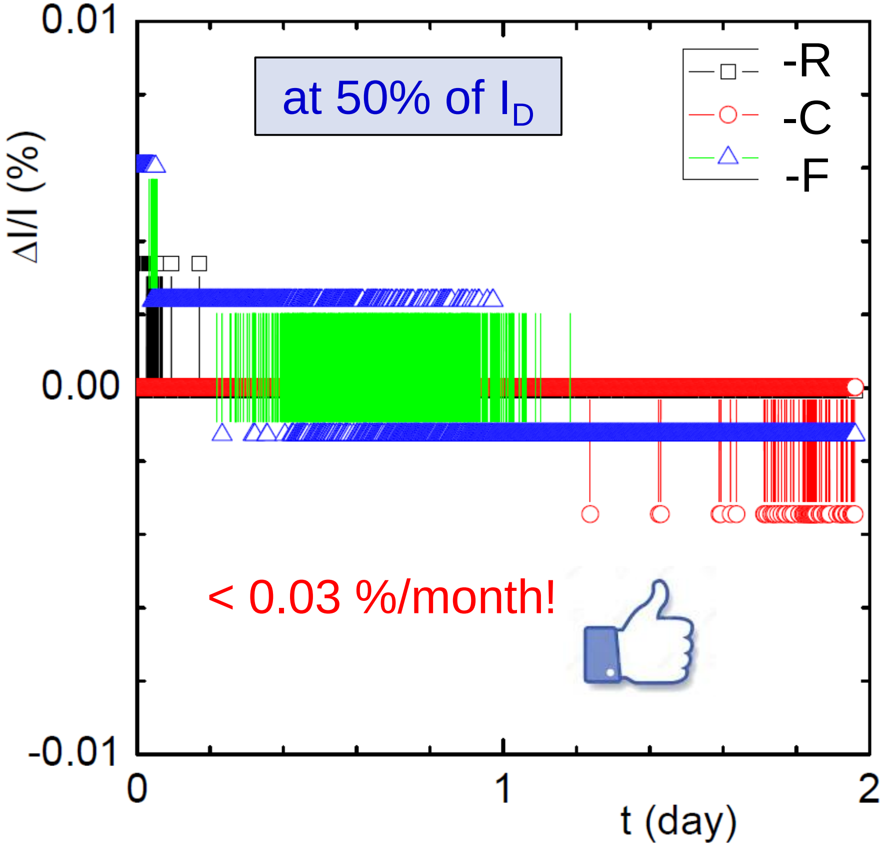


→ Unobstructed electron transmission for the designed magnetic flux of 191 Tcm^2

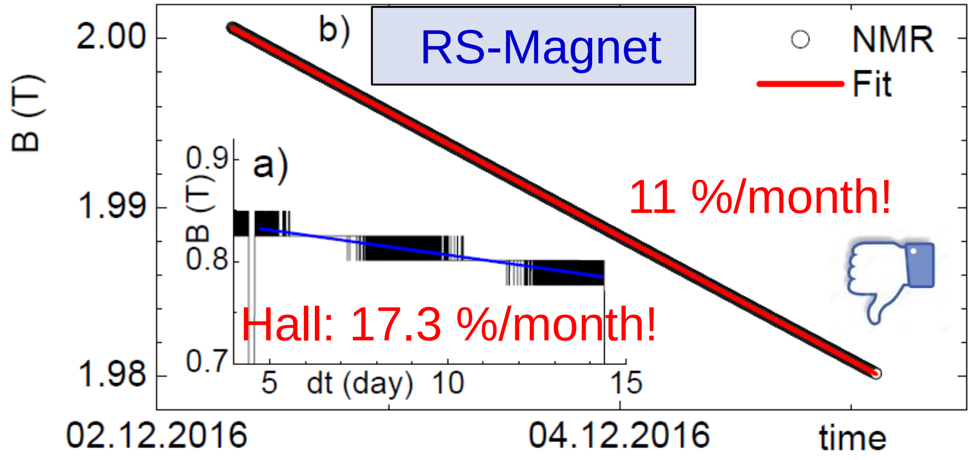
B-field stability of the magnets

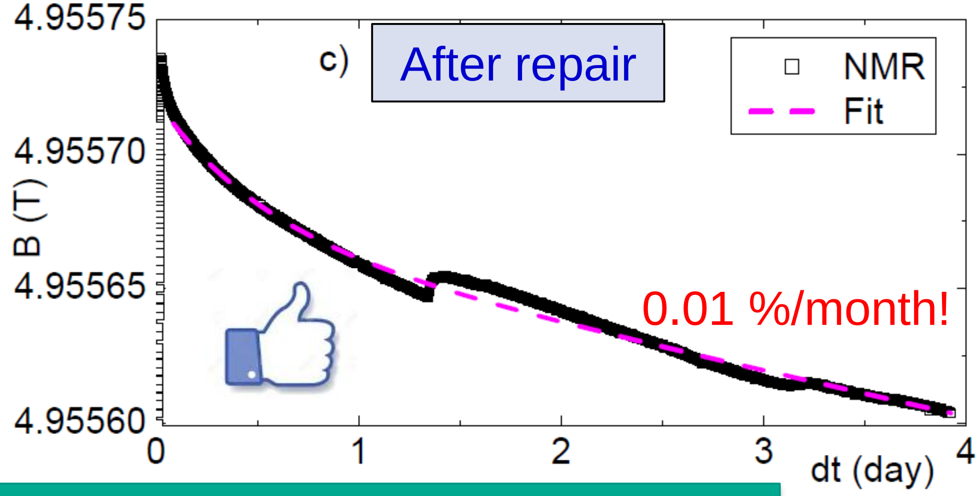


- B-field drift of the WGTS in driven mode



- B-field drift of the RS magnet in persistent mode

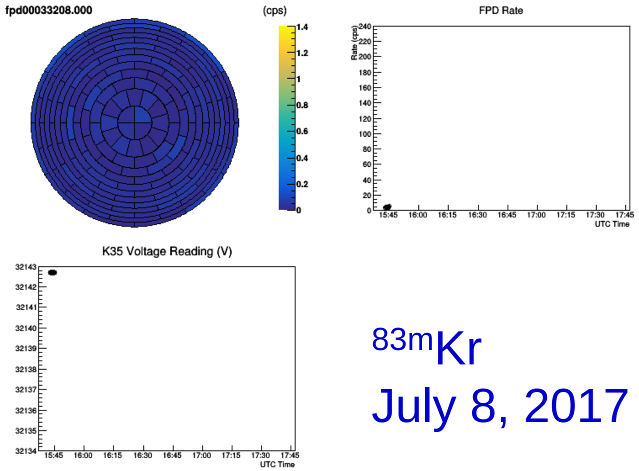




→ The B-field stabilities of all the magnets are within the specification!

Summary and Outlook

- Summary
  - Successful first light test in Oct. 14, 2016,
    Successful commissioning measurements with ^{83m}Kr at 70 % of I_D in July, 2017.
  - Two weeks continuous operation of the complete KATRIN magnets without cooling issue.
  - Magnetic field stability of the magnets are within the specifications.
  - Unobstructed electron transport in the magnetic flux of 191 Tcm^2
  - Distinct quench detection by MSS allows us to save a large amount of LHe and cryogenic recovery time!



^{83m}Kr
July 8, 2017

- Outlook
  - First tritium data in June, 2018 after tritium loops' completion.
  - KATRIN operation for about 5 years, meaning 3 years effective data taking

Thank you for your attention!

Karlsruhe Institute of Technology

KATRIN
Karlsruhe Tritium Neutrino Experiment

KATRIN

Collaboration:

130 members,

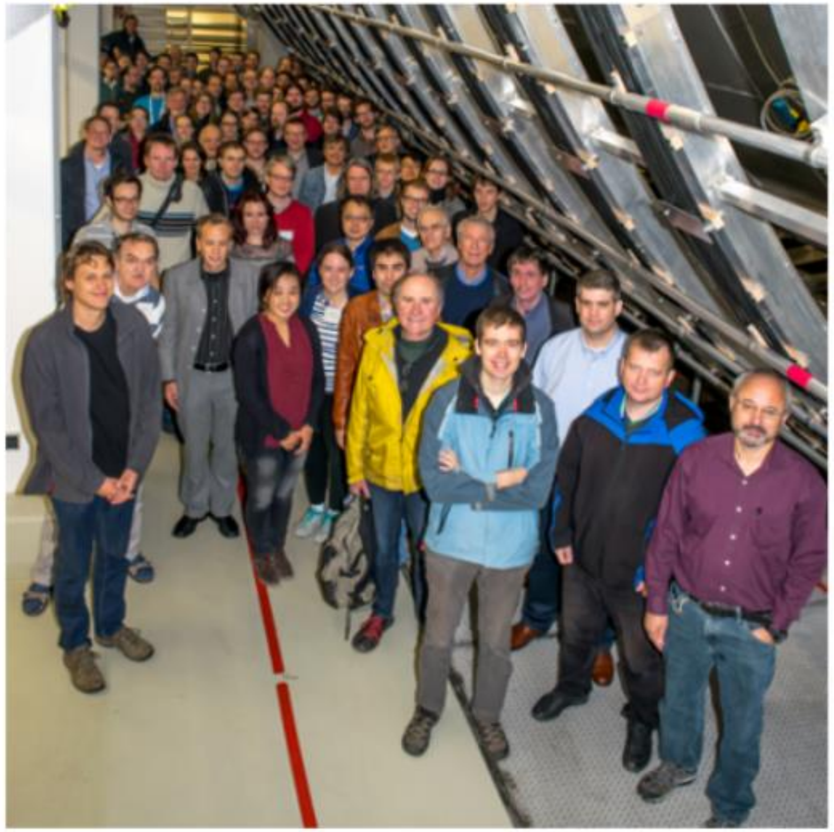
19 institutions

in 5 countries:

DE, US, UK,

CZ, RUS

cea
University of Washington
Westfälische Wilhelms-Universität Münster
Berkeley Lab
The Czech Academy of Sciences
Massachusetts Institute of Technology
Hochschule Fulda University of Applied Sciences
Russian Academy of Sciences
Max-Planck-Institut für Physik
The University of North Carolina at Chapel Hill



universität bonn
Max-Planck-Institut für Kernphysik
Johannes Gutenberg Universität Mainz
Carnegie Mellon University
Technische Universität München
Karlsruhe Institute of Technology
Case Western Reserve University Est. 1826
Universidad Complutense Madrid
Bergische Universität Wuppertal

http://www.katrin.kit.edu/

- Supplemental slides

MAIN DATA OF THE KATRIN S.C. MAGNETS

Items	WGTS-R	WGTS-C	WGTS-F	CPS	RS	DPS	PS	PCH	DET
Mode	DM	DM	DM	DM	PM	PM	PM/DM	PM	PM
I_d (A)	309.85	308.84	208.84	200	66.71	71.02	157	86.98	56.154
B_d (T)	3.6	3.6	5.6	5.6	4.7	5.0	4.5	6.0	3.6
L (H)	27.1	33.6	74.5	172	291	290	77.3	428	653
E (MJ)	1.30	1.60	1.62	3.44	0.65	0.73	0.95	1.62	1.03
J (A/mm^2)	151	151	100	117	144	155	160	196	185
Modules	3	2	2	7	1	5	2	1	1
Coils	9	6	6	7	3	15	2	3	1