The COherent Muon to Electron Transition (COMET) experiment at J-PARC (Japan)

The COMET project at JINR

Report

on the results

and extension request for the period 2021-2023

JINR COMET team

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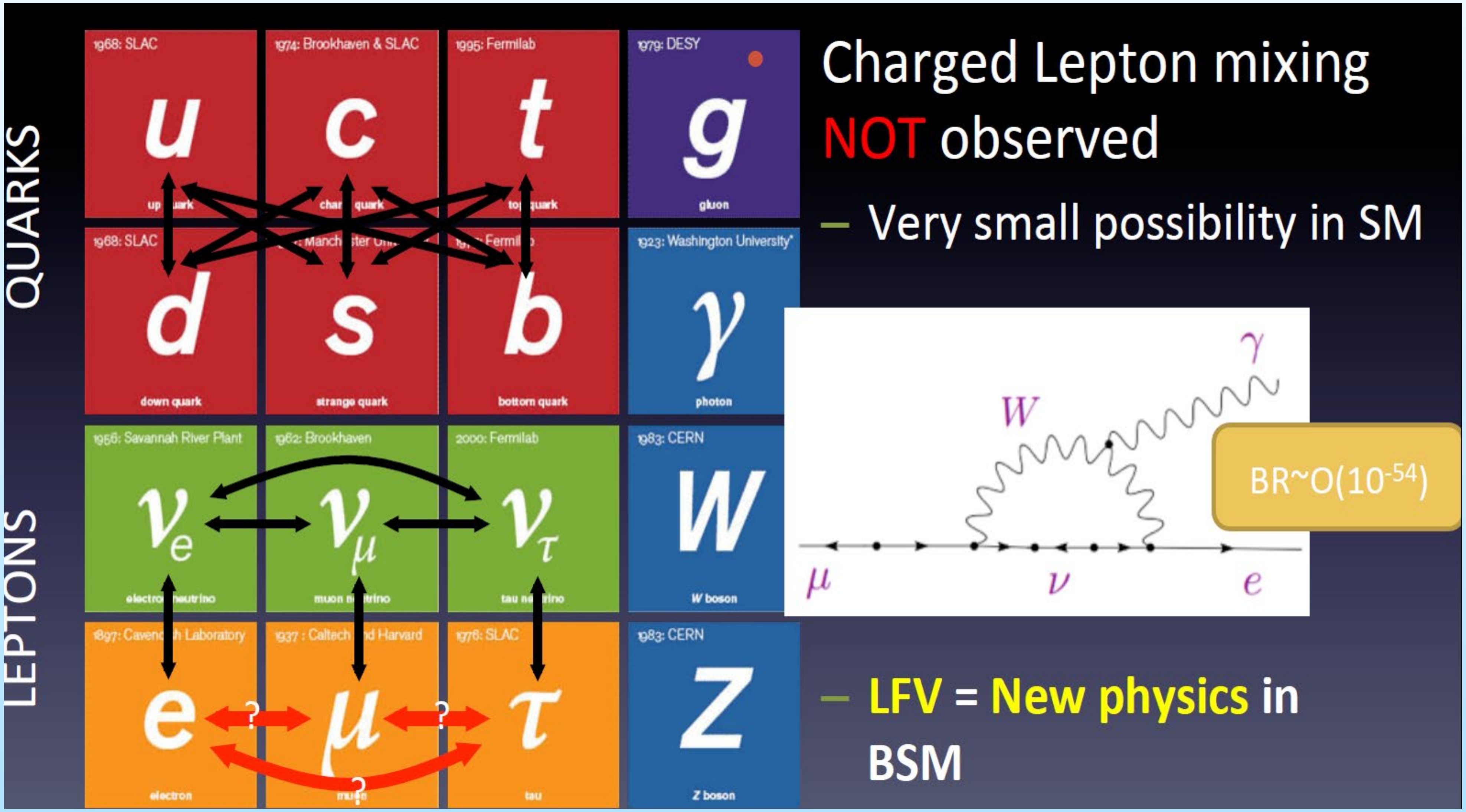
Charged Lepton Flavor Violation (CLFV)



Charged-lepton flavor-violating (cLFV) processes offer probes for new physics with discovery sensitivity.

The most sensitive probes of CLFV utilize high-intensity muon beams.

WHAT IS THE NEXT STEP ? AND WHERE?

Frontiers of particle physics

a. Energy Frontier

using high-energy colliders to discover new particles and directly probe the architecture of the fundamental forces. Many theories predict particles with masses > 1 TeV. **CERN, FCC (2040?)**

b. Intensity Frontier

using intense particle beams to uncover properties of neutrinos and observe rare processes that will tell us about new physics Beyond the Standard Model (BSM). **J-PARC, Fermilab, PSI**.

c. Cosmic Frontier

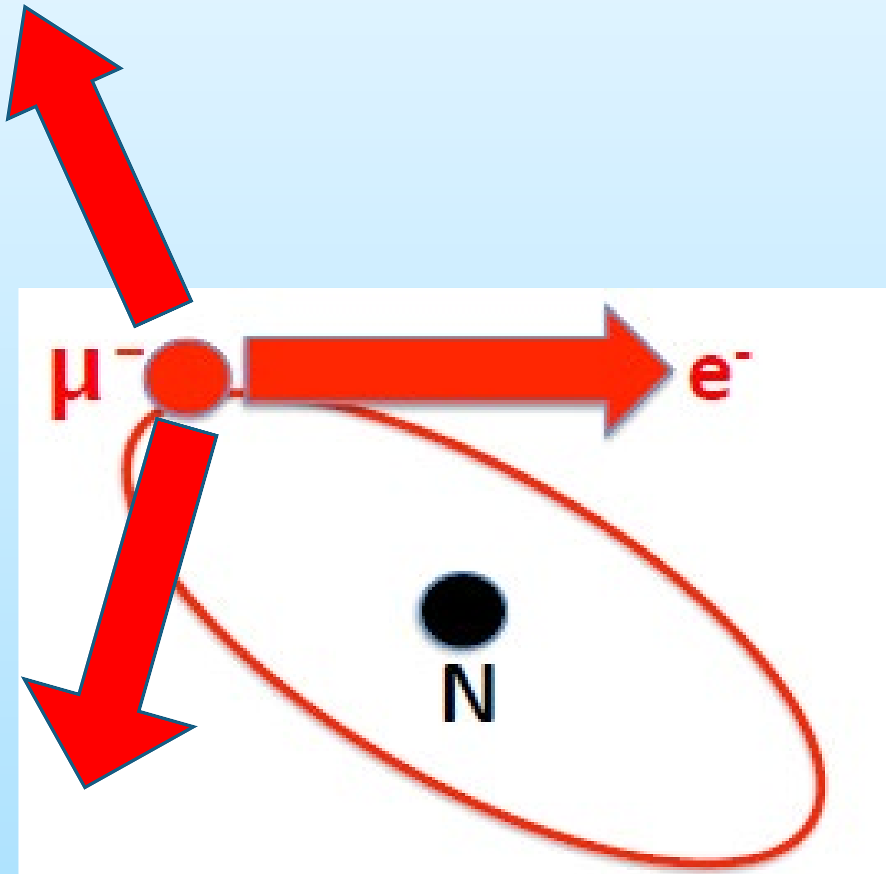
using underground experiments and telescopes, both ground and space based, to reveal the natures of dark matter and dark energy and using high-energy particles from space to probe new phenomena.

μ-e Conversion

Muon decay in orbit **39% in Al**

$\mu^- \longrightarrow e^- \nu_\mu \bar{\nu}_e$

Standard Model Processes



Nuclear muon capture **61% in Al**

$\mu^- + (A,Z) \longrightarrow \nu_\mu + (A,Z-1)$

New Physics Process

Neutrino-less nuclear capture of a muon
(= μ-e conversion)

$\mu^- + (A,Z) \rightarrow e^- + (A, Z)$

muonic atom — single mono-energetic electron.

$E_e = m_\mu - E_{recoil} - E_{binding} = 104.97\text{MeV (Al)}$

Muon lifetime in Al ~ 864ns

	L_e	L_μ	L_τ
ν_e, e^-	+1	0	0
ν_μ, μ^-	0	+1	0
ν_τ, τ^-	0	0	+1

$\Delta L_{\mu,e} = 1$
$\Delta L = 0$

Lepton flavors change in this process

- Measure the ration of conversion relative to ordinary muon capture on the nucleus:

$$B(\mu^- N \rightarrow e^- N) = \frac{\Gamma(\mu^- N \rightarrow e^- N)}{\Gamma(\mu^- N \rightarrow \nu N')}$$

, (where N´ = (A, Z-1); or (A´,Z´) + protons, neutrons, gammas)

The COMET collaboration

The COMET Collaboration

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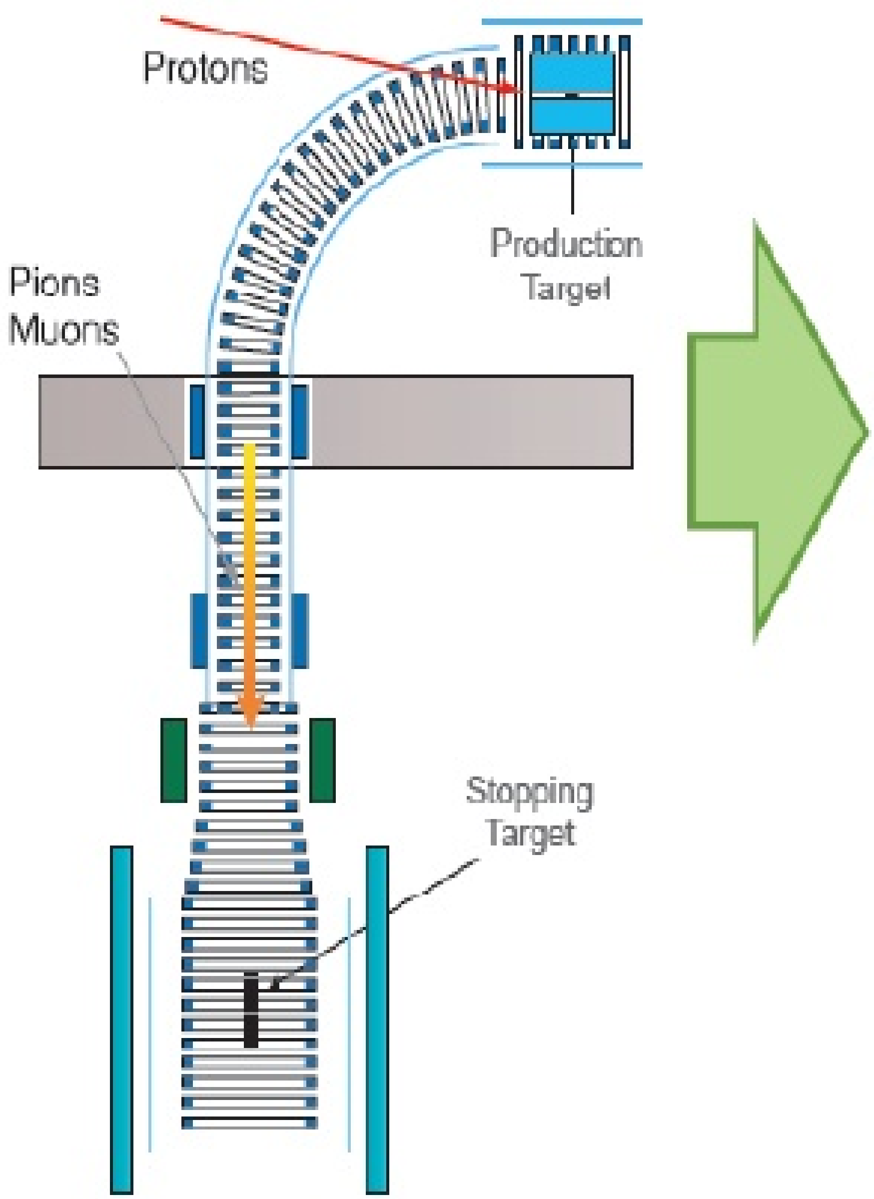
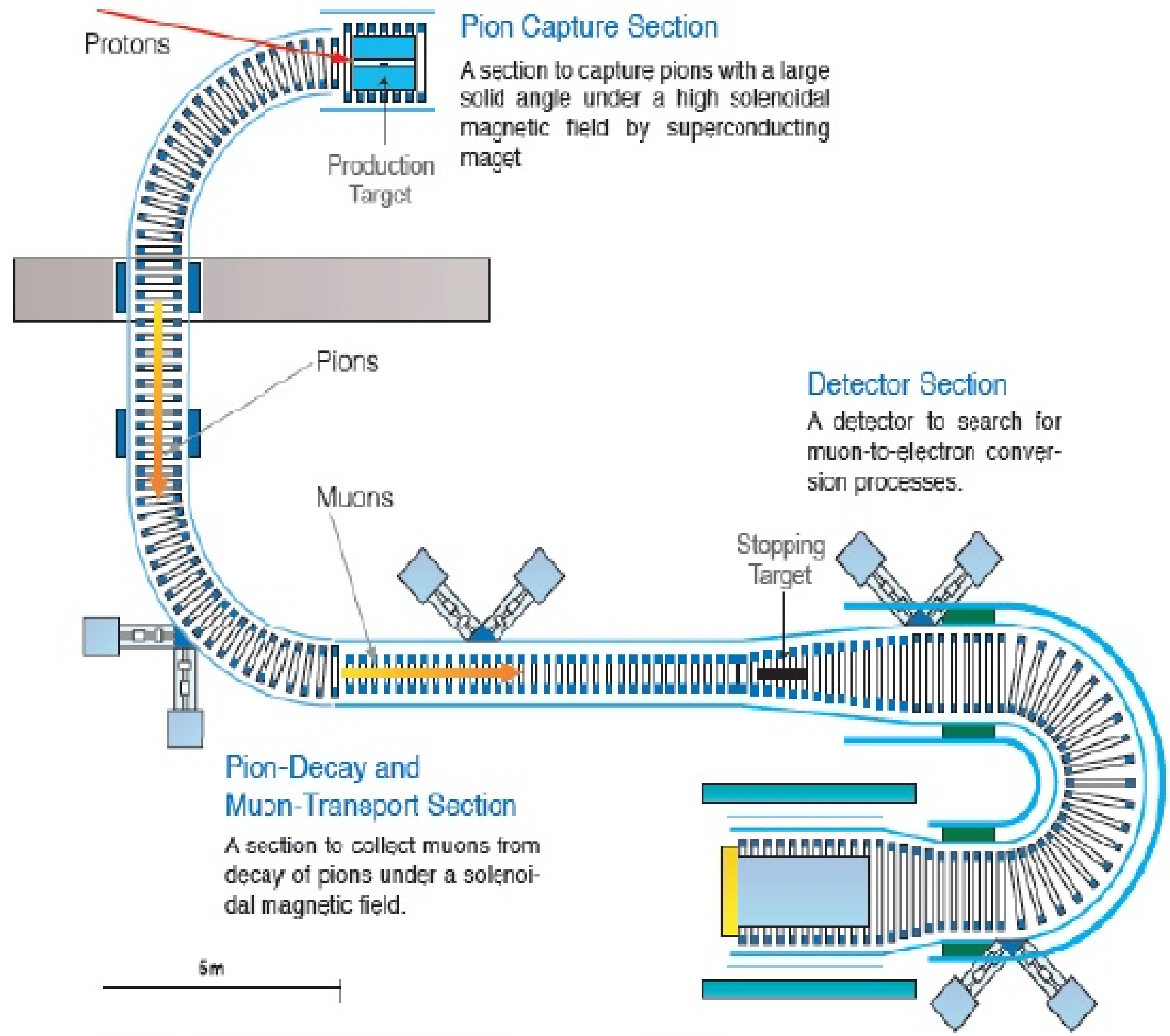
about 200 collaborators
41 institutes, 17 countries

Still growing!

Including five JINR member states countries
Belarus, Czech Republic, Georgia, Kazakhstan, Russia

Two-phase realization





Muon beamline up to the end of the first 90^0 bend

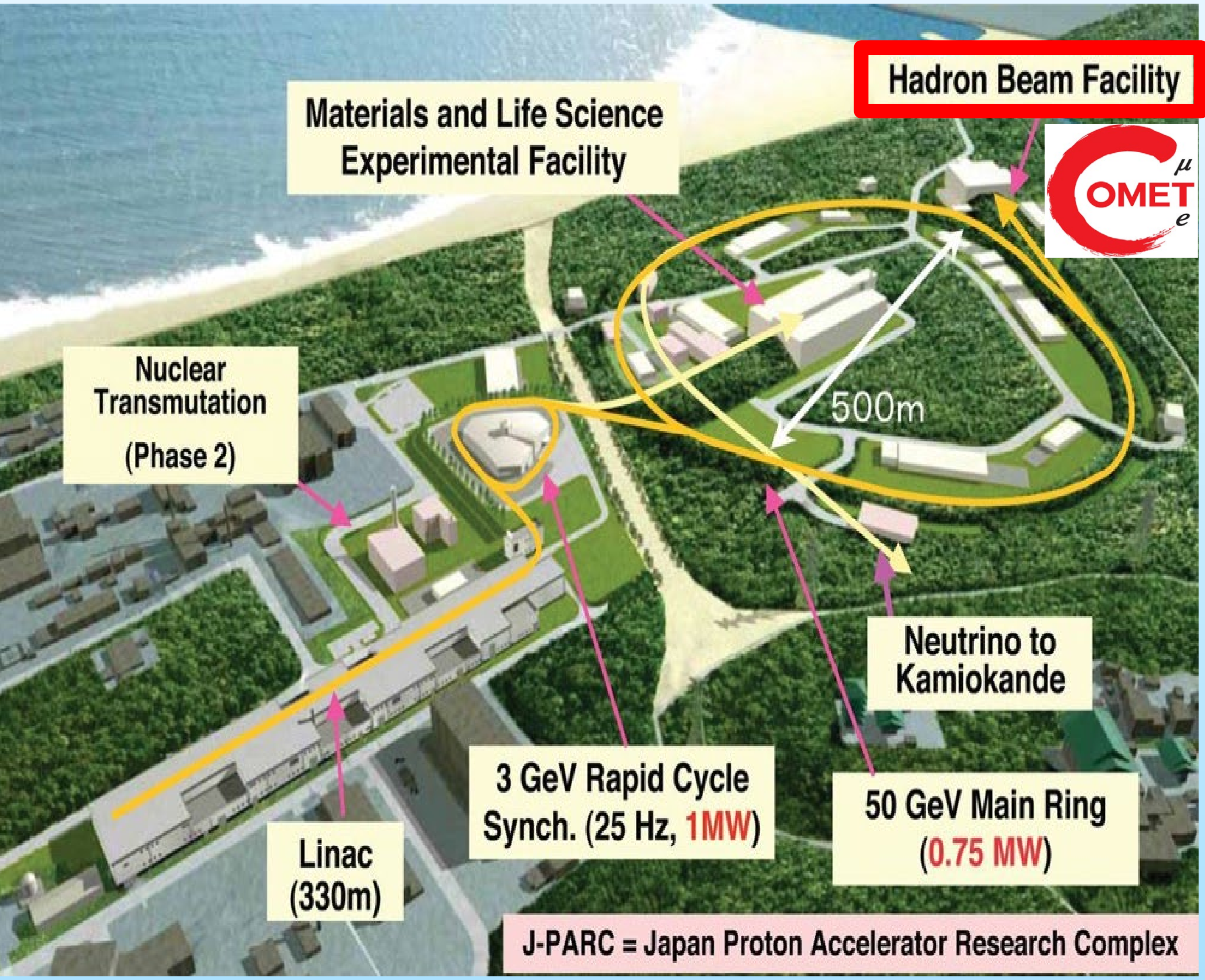
COMET Phase-I

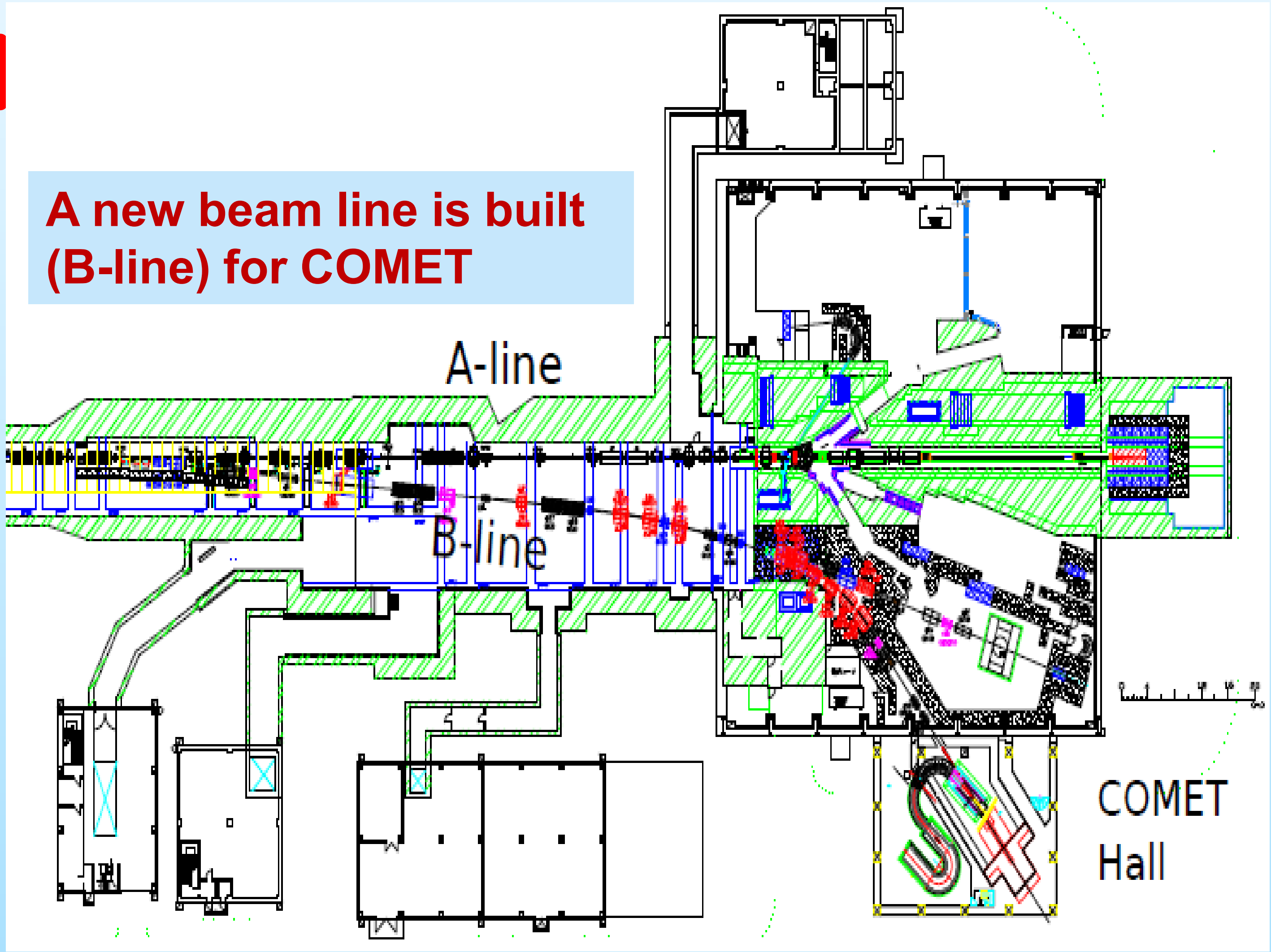
Start from 2022

COMET Phase-II

Start from 202?

COMET at J-PARC



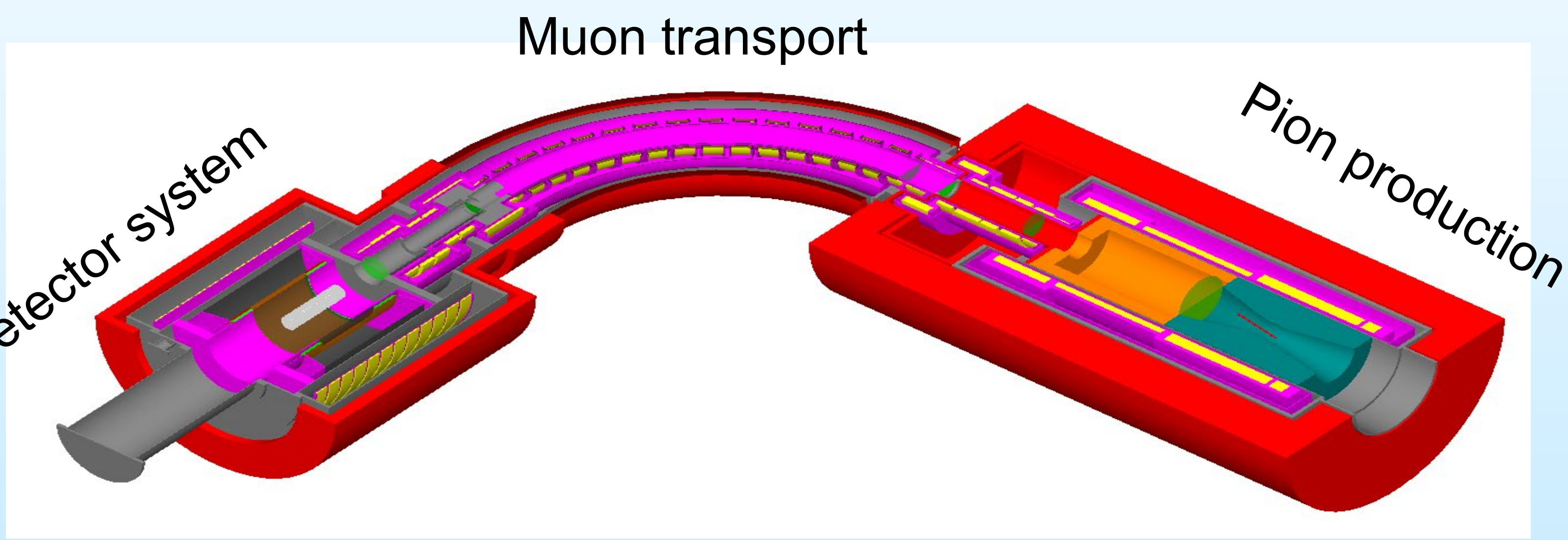


Joint Project between KEK and JAEA

Proton beam and power
for COMET Phase – I and Phase - II

	Phase – I	Phase - II
	8GeV	8 GeV
	3.2kW	56kW

COMET phase-I



COMET Phase-I system

1 Search for μ-e conversion

- A search for μ-e Conversion at the intermediate sensitivity with would be 100-times better than the present limit (SINDRUM-II) 3×10^{-15}

2 Background Study for the full COMET Phase-II

- Direct measurement of potential background sources for the full COMET experiment by using the actual COMET beam line

COMET Phase-I serves several roles that are highly complementary to the Phase-II experiment. It provides a working experience of many of the components to be used in Phase-II and enables a direct measurement of backgrounds. Significantly it will also produce competitive physics results, both of the μ−e conversion process that is the primary focus of COMET Phase-II, and of other processes that COMET Phase-II cannot investigate.

COMET Phase-I Requirements and Detectors

How to reach unprecedentedly high sensitivity ($7.0 \times 10^{-13} \rightarrow 10^{-15,-17}$)

COMET Requirements:

1. Reduce Beam Associated Background

Pulsed proton beam with high proton extinction and used the long μ lifetime

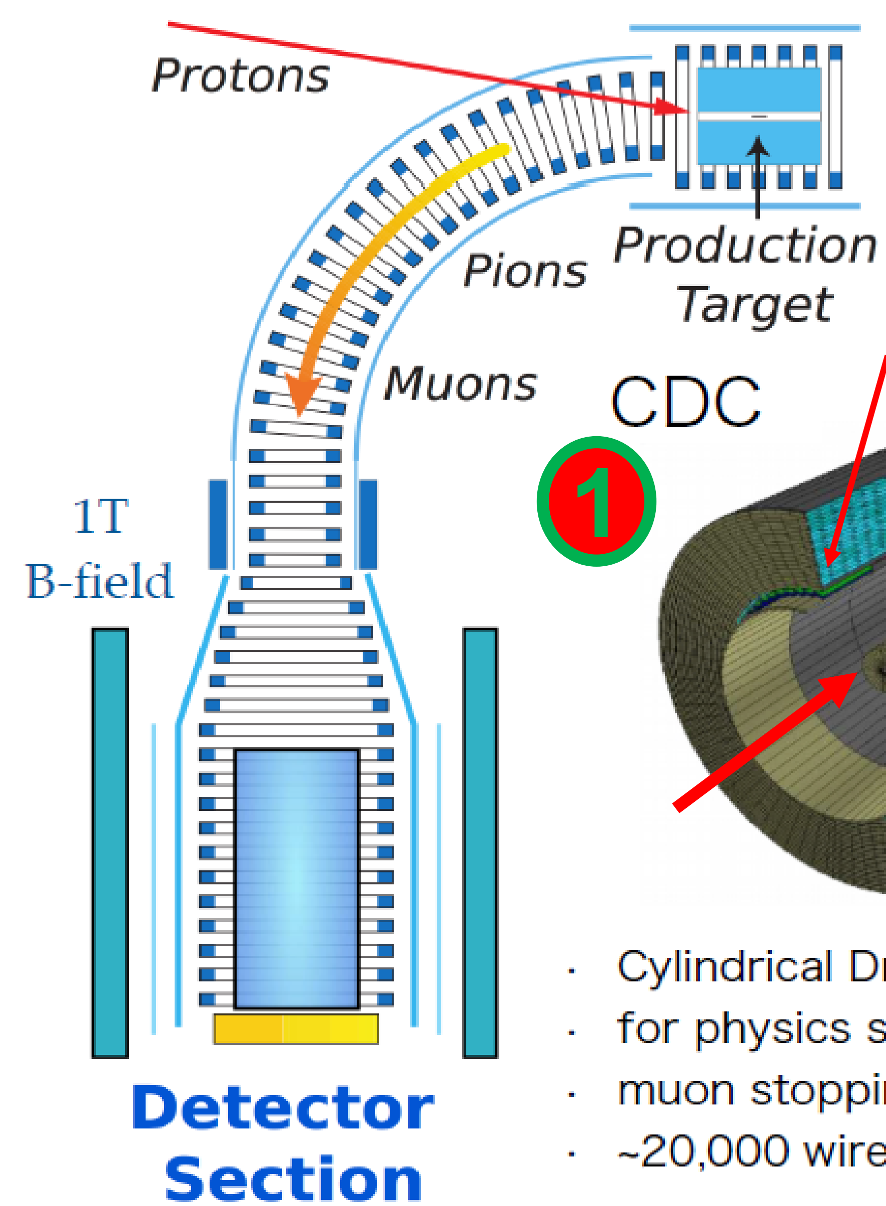
2. Highly intense muon source

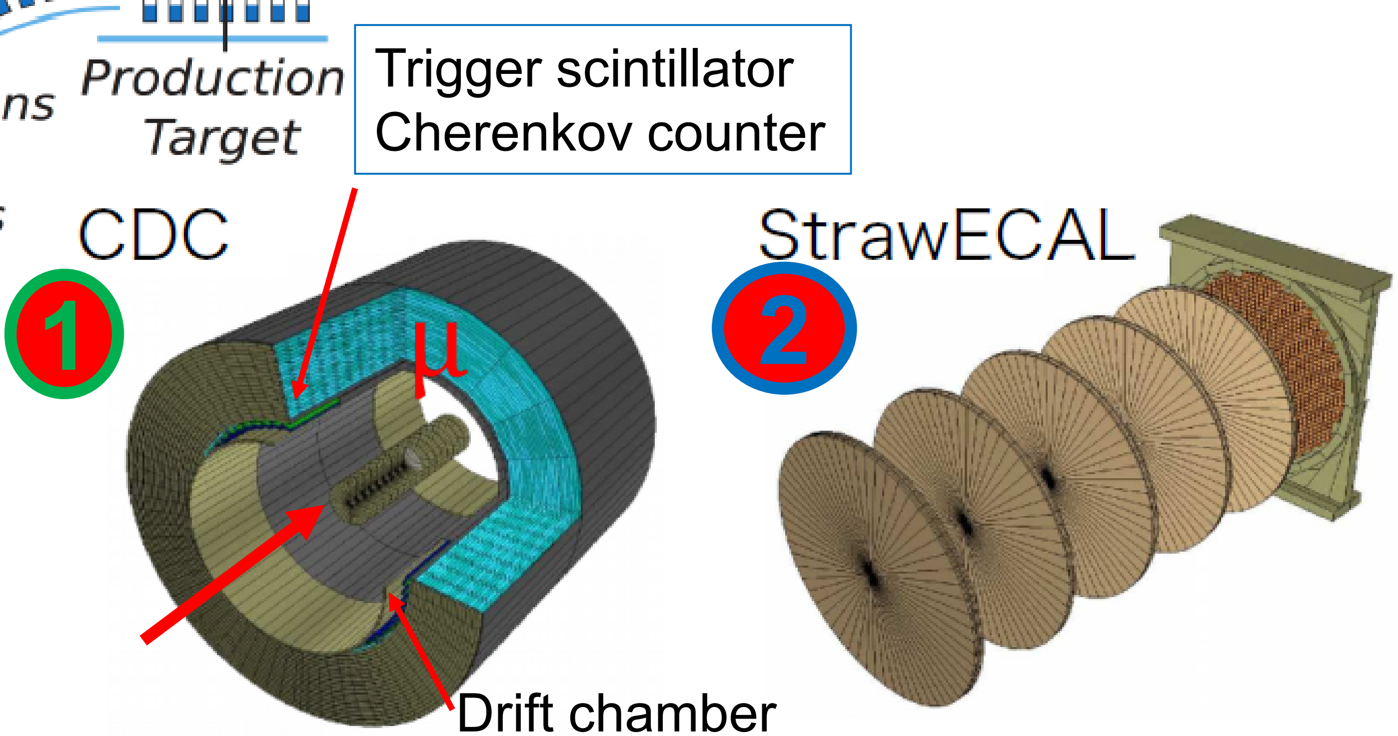
High Intensity Pion Production (μ from π decay)

Use magnetic solenoids to capture, transport, charge and momentum selection, detect μ

3. Curved solenoids for charge and momentum selection, electron Energy Resolution and Timing

Excellent calorimeter and tracking detectors,
employ new electronic technology to handle higher rates.





- Cylindrical Drift Chamber
- for physics search in Phase-I
- muon stopping target at center
- ~20,000 wires with He base gas

- Straw Tracker
- + Energy Calorimeter
- for background measurement
- also as R&D for Phase-II

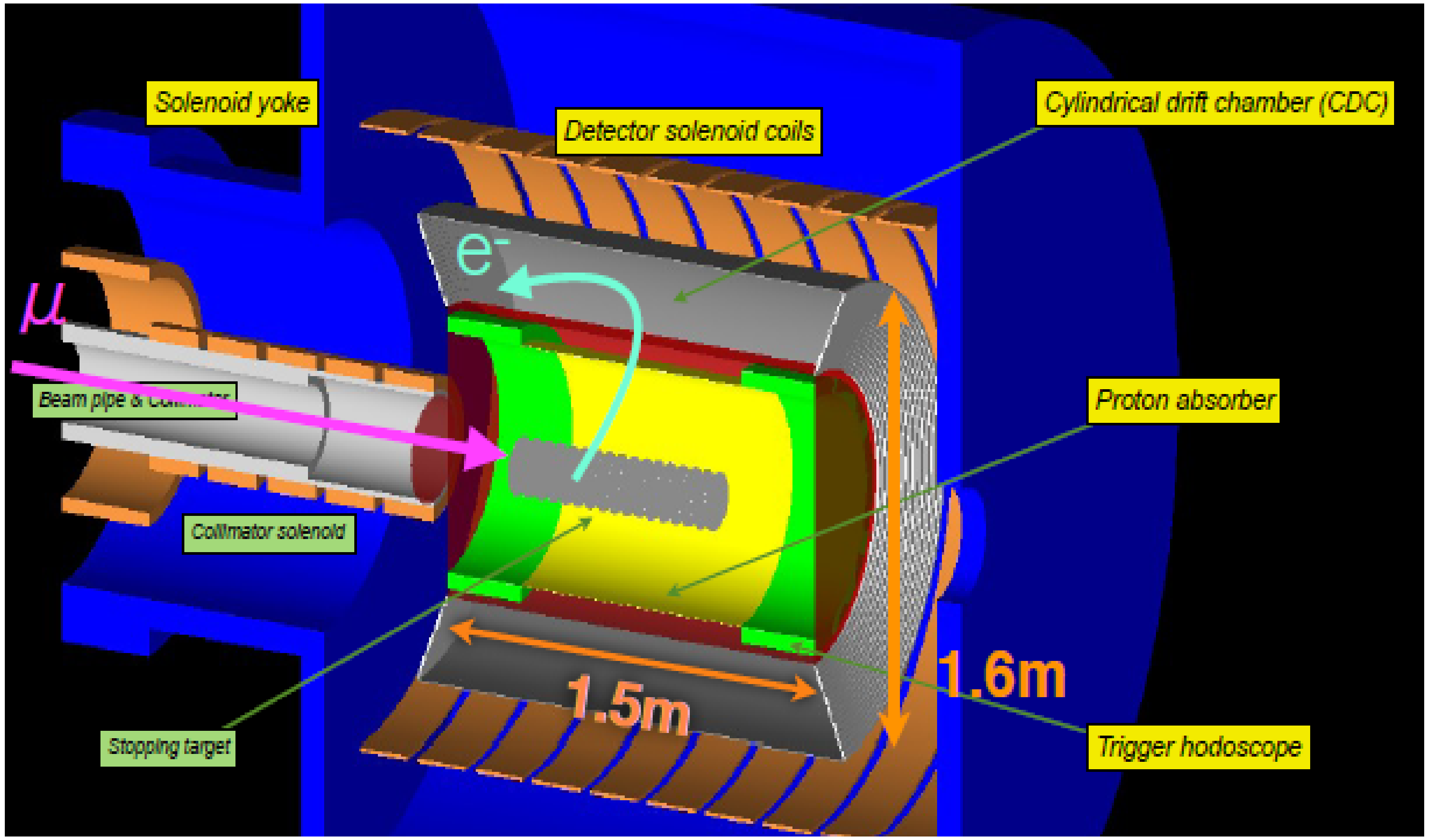
Target length	600 mm
Target radius	20 mm
Target material	graphite

One advantage of a graphite target is that it is a refractory material and so is tolerant to high Temperature (175-190) operation

Item	
Material	aluminium
Shape	flat disk
Radius	100 mm disk
Thickness	200 μm
Number of disks	17
Disk spacing	50 mm

For Phase-I a total number of protons on target (POT) of 3.2×10^{19} is planned which will provide around 1.5×10^{16} muons stopped in the target

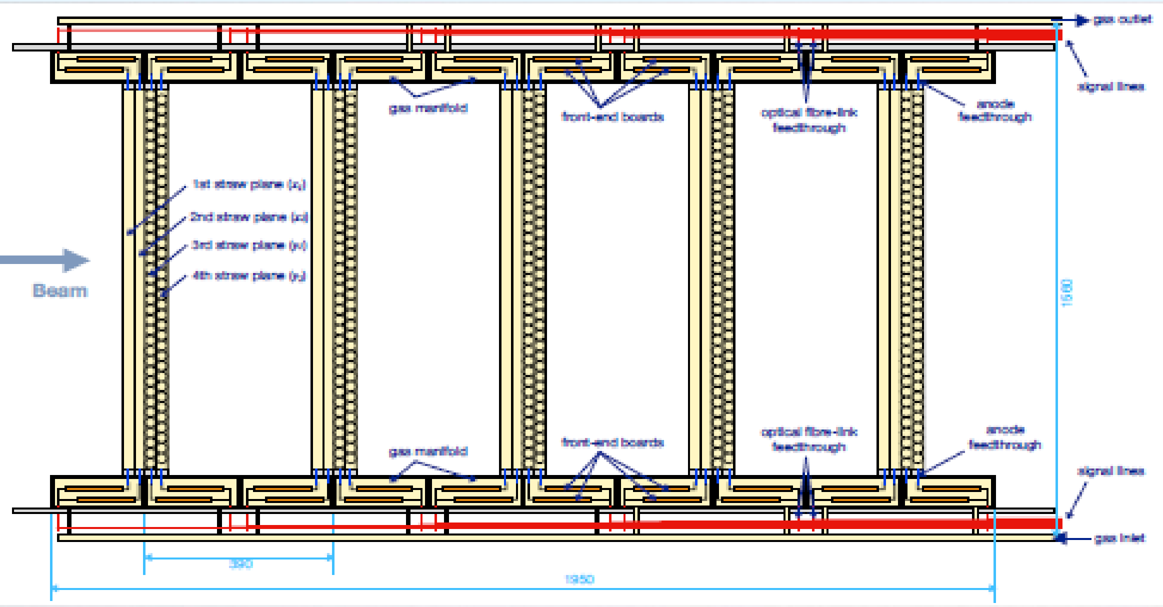
Cylindrical Drift Chamber



COMET CDC

- Surrounding target
- 19 layers structure
  - ~5,000 sense wires
  - ~15,000 field wires
- All stereo layers
- He base gas
  (He : iC_4H_{10} = 10 : 90)
- Study of prototype chamber is done
  - basic performance study was done, it is OK
  - spatial resolution < 200 μm obtained,momentum resolution <200 keV/c
  - wire aging test is almost done
- Design was fixed based on Belle-II CDC with modification for COMET
- Construction started in 2014, and completed in 2016
- Commissioning with cosmic-ray is ongoing in KEK now

Straw Tracker: 5 station (Phase – I)~ 2500 straw tubes, 9.75 mm diameter, 20 μm thickness, Ar:C_2H_6 = 50:50

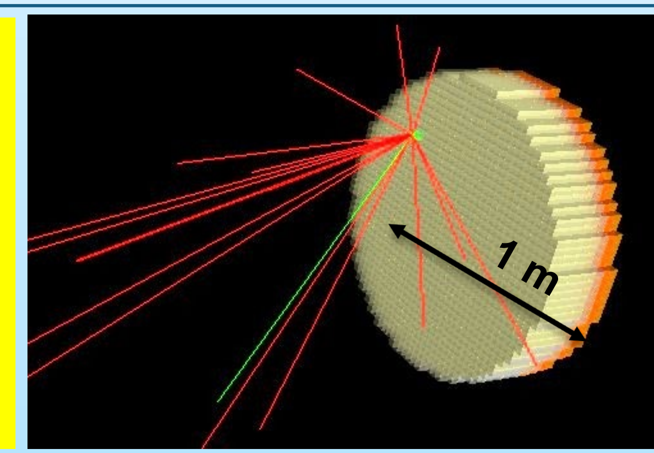


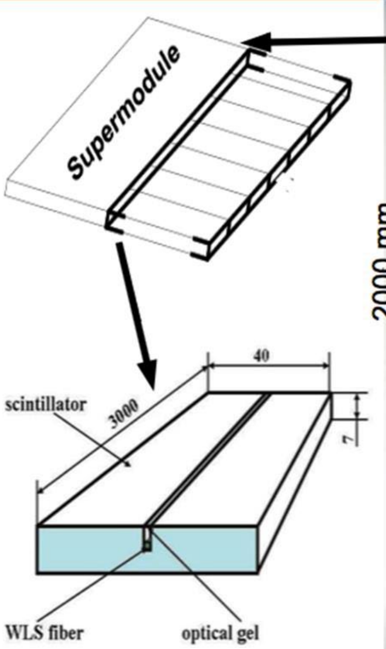
Requirements:
- Work in vacuum, magn. field 1 Tesla
- Momentum resolution ≤ 200 keV/c
- Space resolution ≤ 200 μm

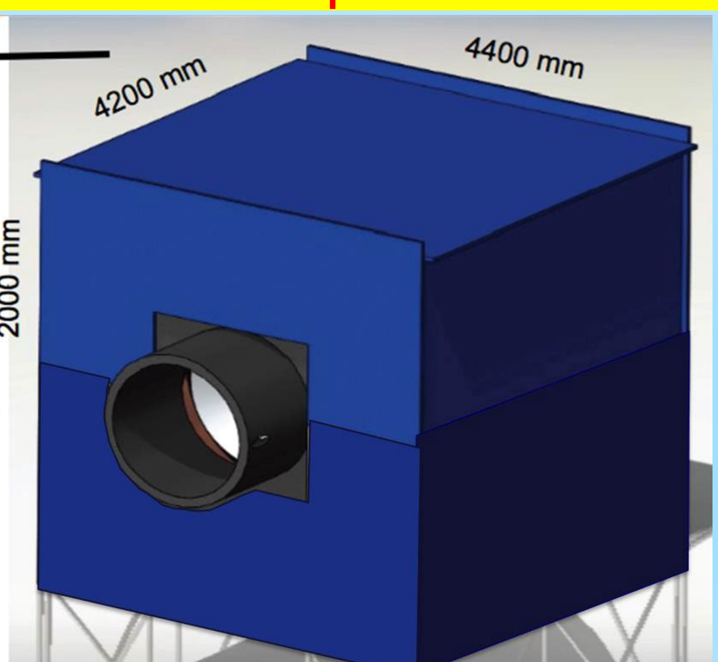
Electromagnetic calorimeter

ECAL (crystal type LYSO, $Lu_{1.8}Y_{.2}SiO_5Ce$)
- Combination of around 600 (for Phase II 2272) LYSO crystals.
- Total size: diameter ~ 1m
- Crystal size 20x20x120 mm³ (11 radiation length
- Photon detector: APD

Requirements:
- < 5% ER at 105 MeV
- 1 cm space resolution
- < 100 ns time resolution
- Work in vacuum and magnetic field of 1 Tesla







Cosmic Ray Veto (CRV)
- The whole detector will be shielded from cosmic rays by 4 layers of plastic scintillators (active shield).
- CRV consists of 8 supermodules
- The modules are formed from 15 strips
- Strip sizes: 0.7 x 4 x 220 cm³, 1.2 mm diameter WLS

Also used passive shields, 2 meter of concrete and 0.5 m thick steel.

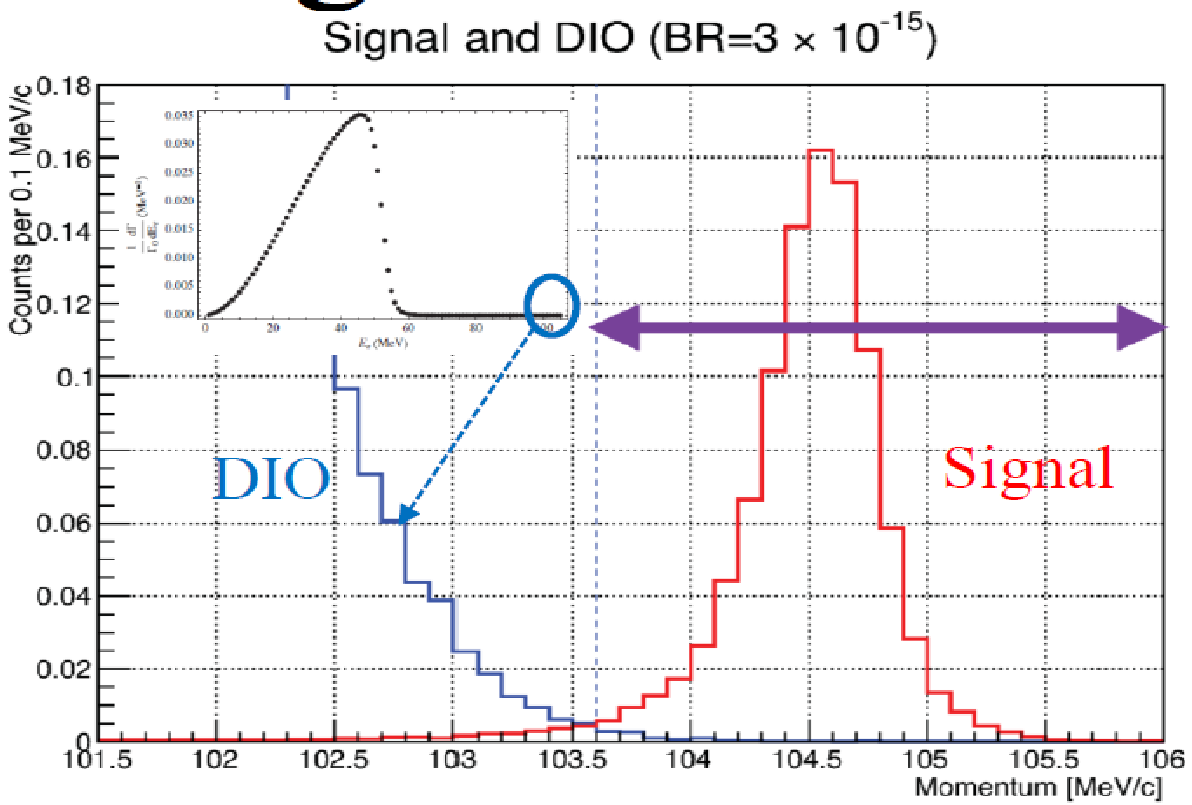
COMET Collaboration will be pleased if JINR team participates in the development and production of CRV system for Phase-I.

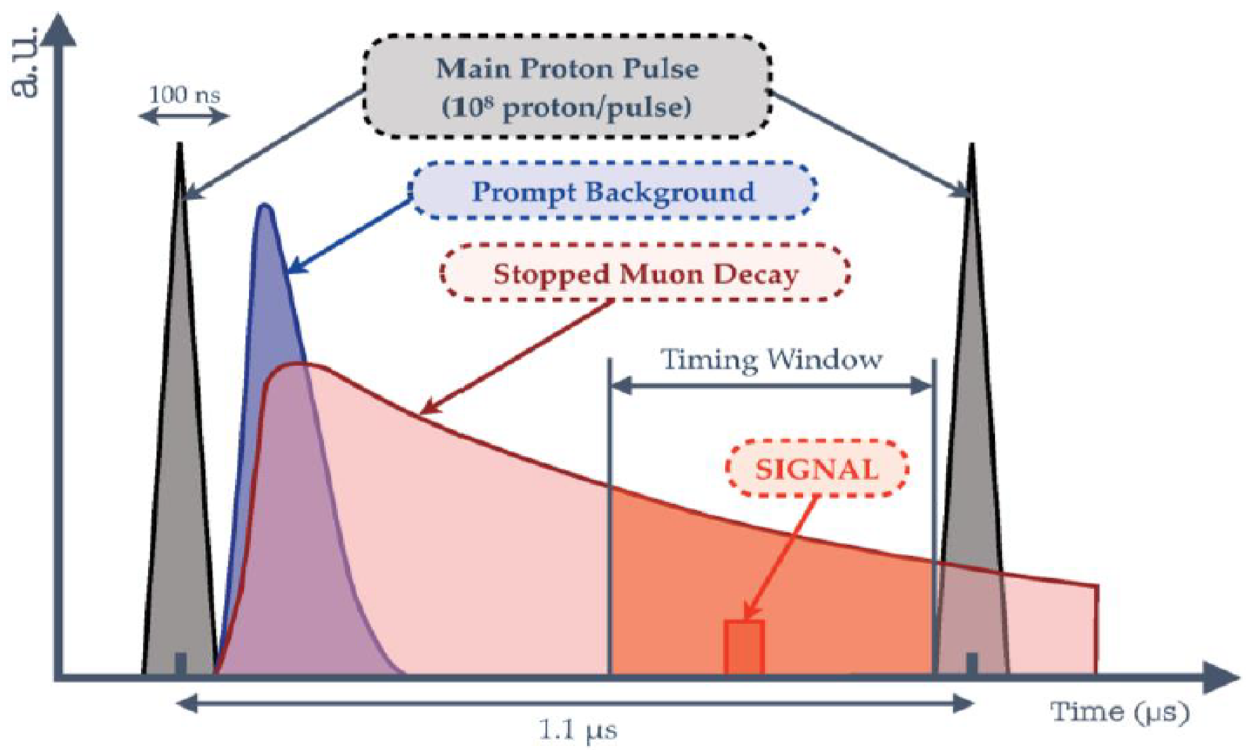
Requirement: Efficiency ≥ 99.99%.

To control the background

- Intrinsic physics background
  - Mostly from muon decay in orbit (DIO)
    - Calculated by Czarnecki with radiative correction. Branching ratio drops with order-5 function near end point.
    - Momentum resolution required to be better than 200 keV/c
- Beam related background
  - Energetic particles in beam with E>100MeV
    - Mostly prompt. Can be suppressed by a delayed measurement window (~700 ns)
    - Some due to leaked proton. Proton extinction factor required to be $< 10^{-10}$。
- Cosmic ray background
  - Cosmic ray: cover the system with cosmic ray veto detectors.

Inefficiency < 10^{-4}





The total estimated background events for a single-event sensitivity of 3 x 10^{-15} in COMET Phase – I with a proton extinction factor 3 x 10^{-11} is 0.032 events

COMET Phase-I Sensitivity

Event selection	Value
Online event selection efficiency	0.9
DAQ efficiency	0.9
Track finding efficiency	0.99
Geometrical acceptance + Track quality cuts	0.18
Momentum window (ε_{mom}) (a signal acceptance)	0.93 **$103.6 < p_e < 106.0$ MeV/c**
Timing window (ε_{time})	0.3 **$700 < t_e < 1170$ ns**
Total (Signal Acceptance for the μ-e conversion)	**0.041**

$$B(\mu^- + Al \rightarrow e^- + Al) = \frac{1}{N_\mu \cdot f_{cap} \cdot f_{gnd} \cdot A_{\mu\text{-}e}}$$

Number of muons stopped inside targets
N_μ = 1.5 x 10^{16}

Fraction of muons to be captured by Al target = 0.61

Fraction of μ-e conversion to the ground state = 0.9

3 x 10^{-15} (as SES) achievable in ~ 150 days, or < 7 x 10^{-15} (as 19% C. L/ upper limit)

JINR group's contributions and responsibilities

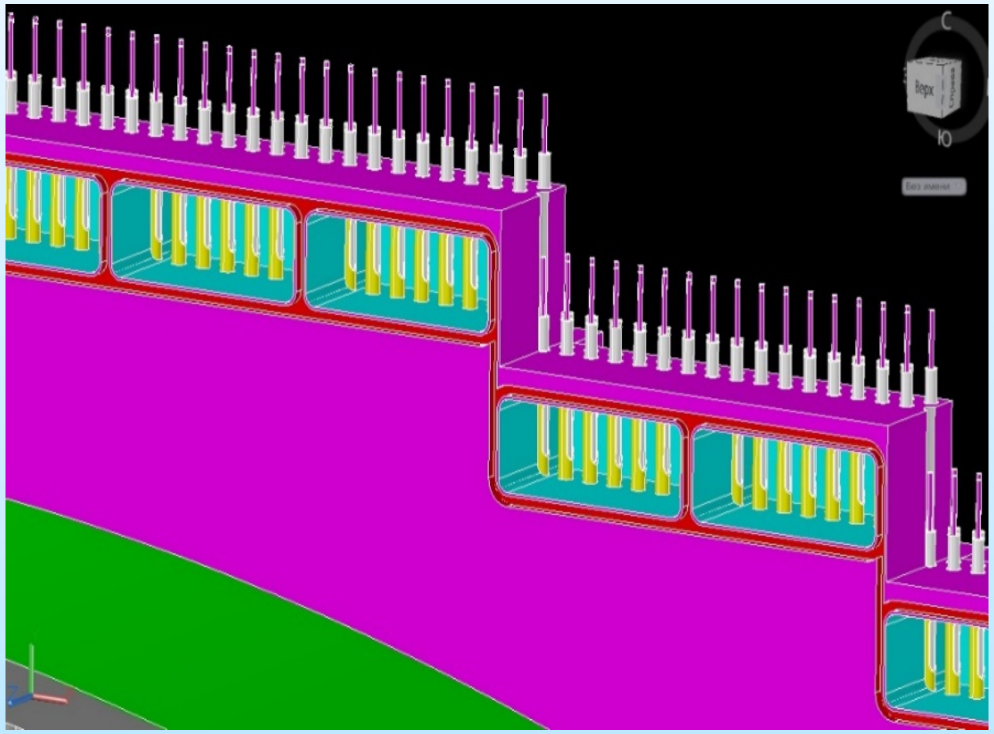
We are in the project since 2008

1. **Straw tracker**
2. **Electromagnetic calorimeter**
3. **Software studies (simulations) for straw tracker and ECAL**
    1. A large amount of work on simulation of processes in crystals and straw detector has been done. **This work continues.**

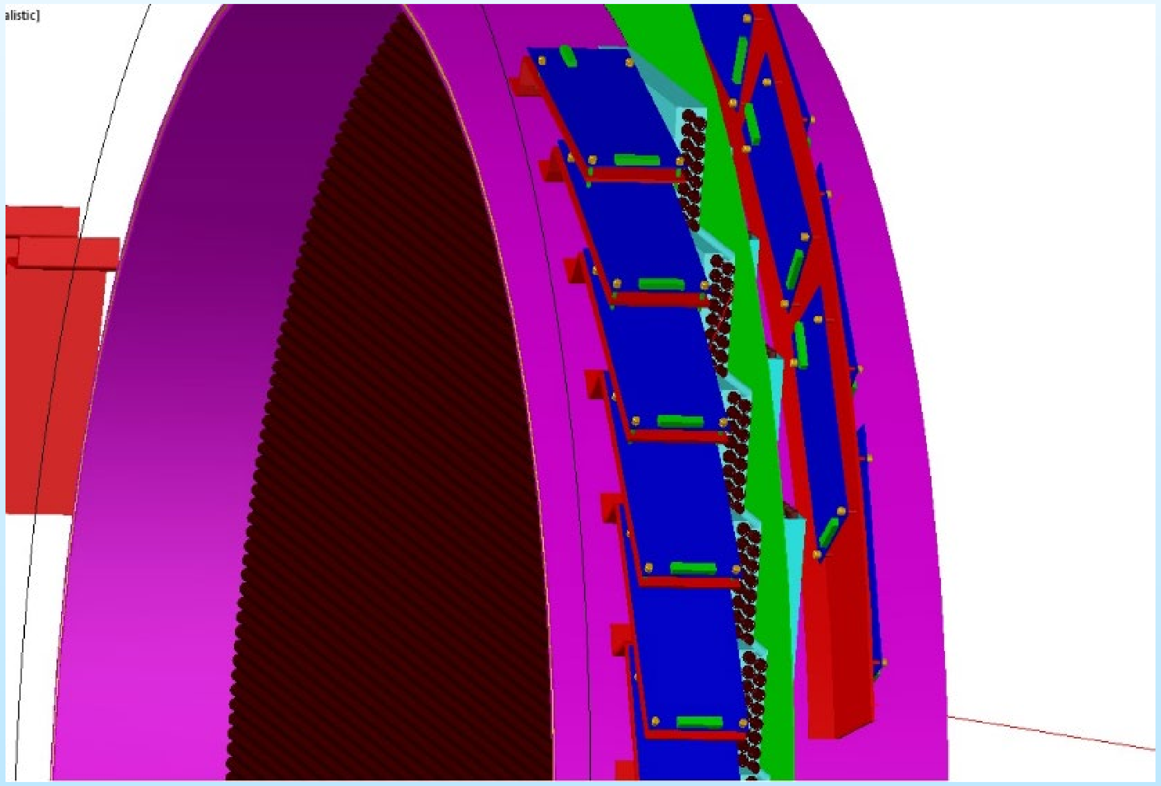
Straw tracker

- Straw module design
- Straw tubes production and testing in Japan
- The study of the properties of straws
- The manufacturing area for straw-tube R&D at DLNP, JINR
- The simulation of straws

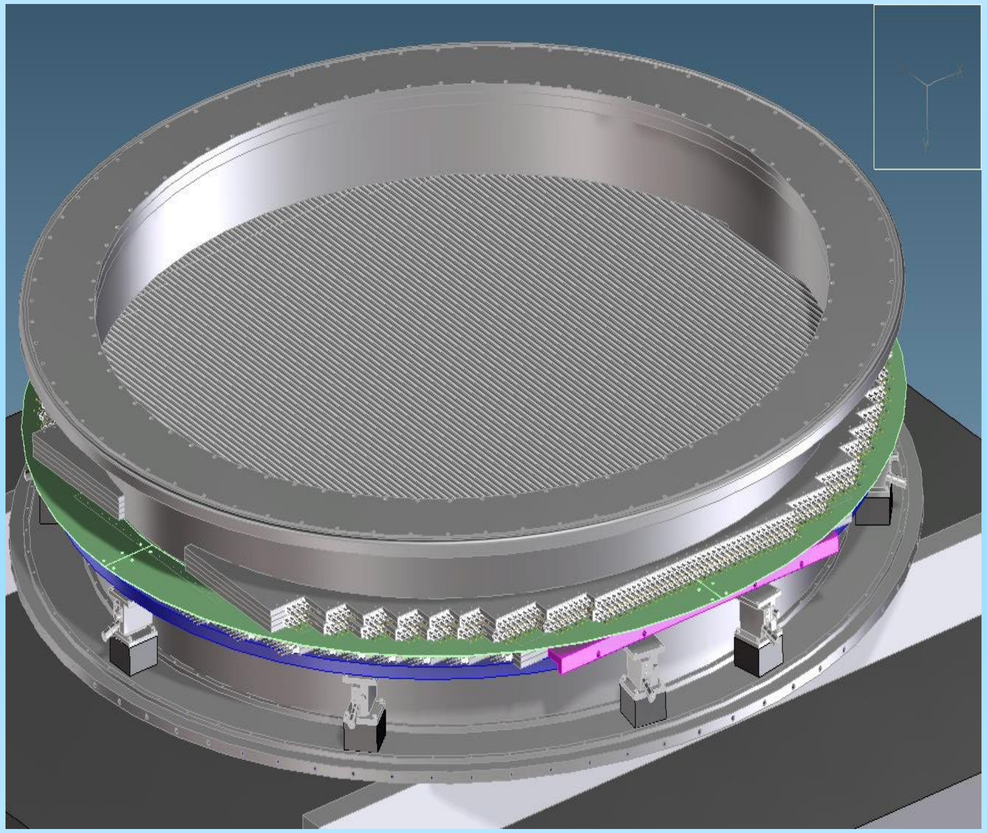
Straw module design



Design of support structure



Schematic view of the ROESTI boards



Design of a complete module

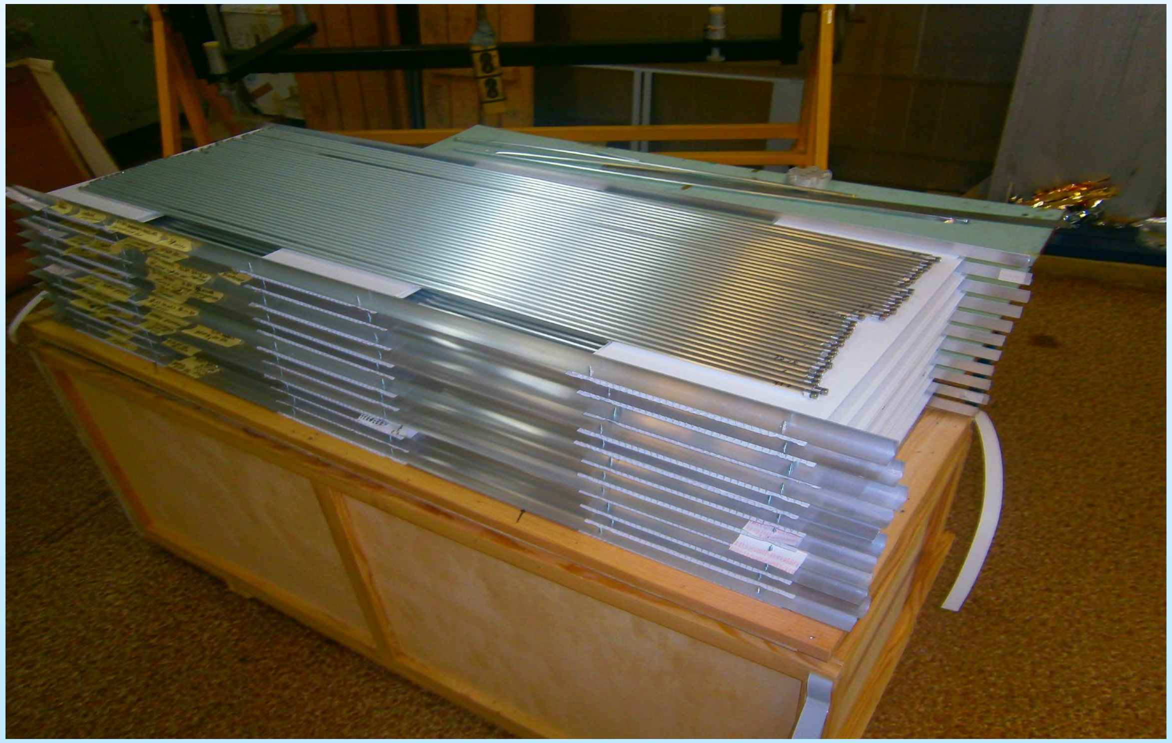
Module contains about 1000 straws with the diameter of 5mm (500 in horizontal direction + 500 in vertical direction) which in its turn means 60 ROESTI boards for both direction have to be allocated along the circular surface which are cooled down by cooling gas

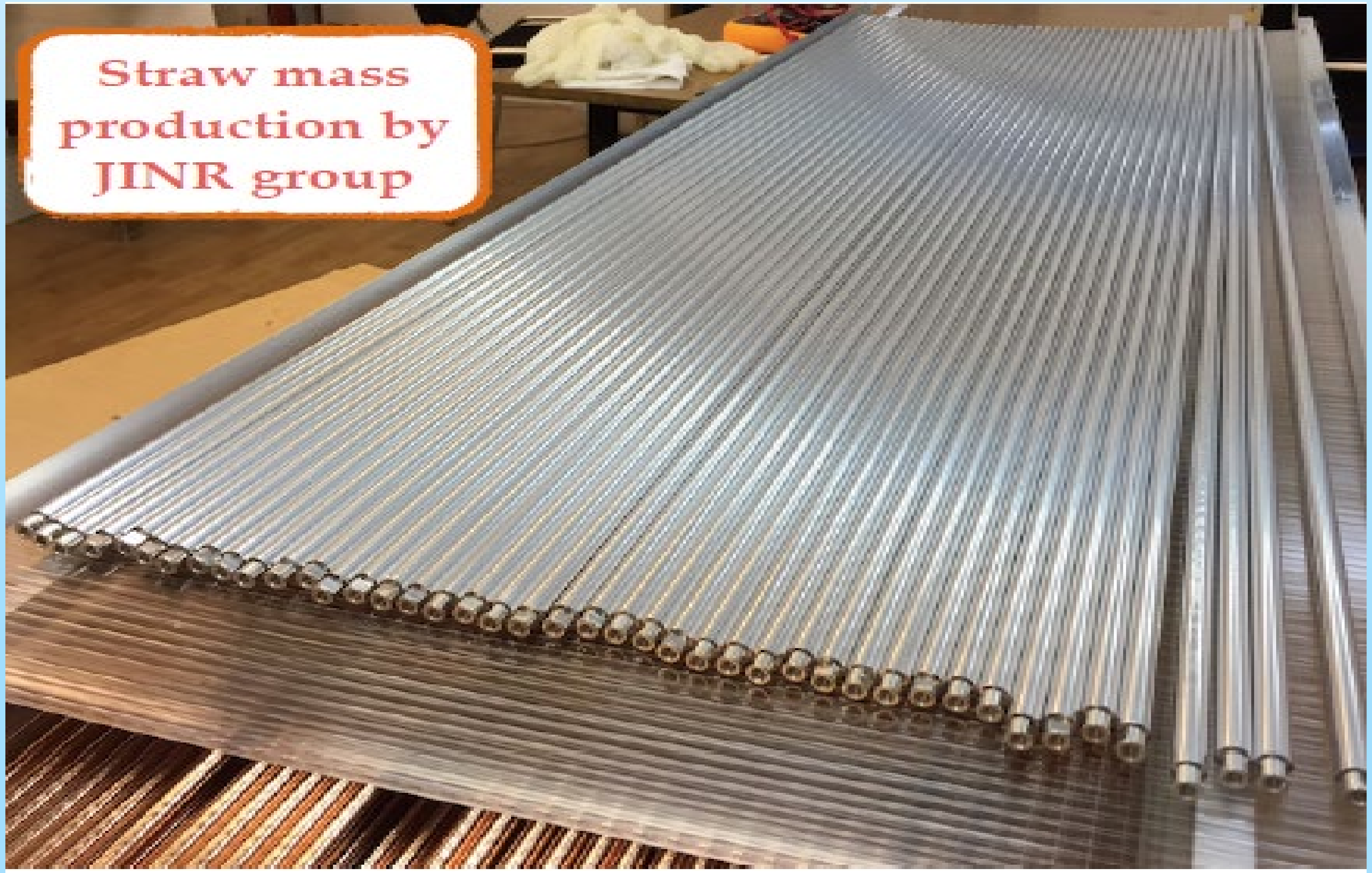
- Next to final design of the straw module for the 5mm diameter straws is developed
- Complete construction documentation for production is in progress
- Also full documentation on the ROESTI board, we will try to produce in RUSSIA, 60pcs.
- If we are lucky to produce the module in time, it can be used for Phase-I measurements

Straw tubes production for Phase-I

The complete set tubes for Phase-I
has been produced and tested:

- 2700 tubes of 20 μ wall thickness, Ø 9.8 mm 120 and 160 cm length have been produced
- These tubes passed all the tests and have been sent to Japan





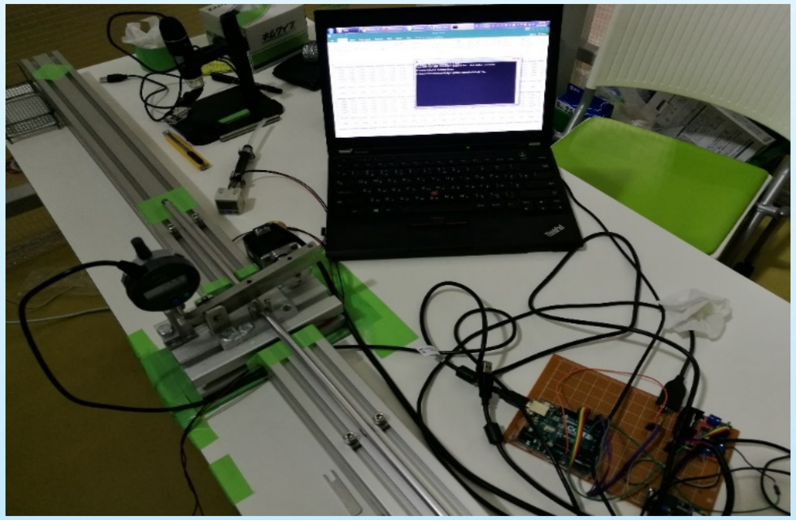
For Phase-II we need even thinner and less diameter tubes:
5 mm diameter and 12 μm wall thickness.
For this purpose we prepared a new straw production line in our laboratory.

Straw tubes testing in Japan

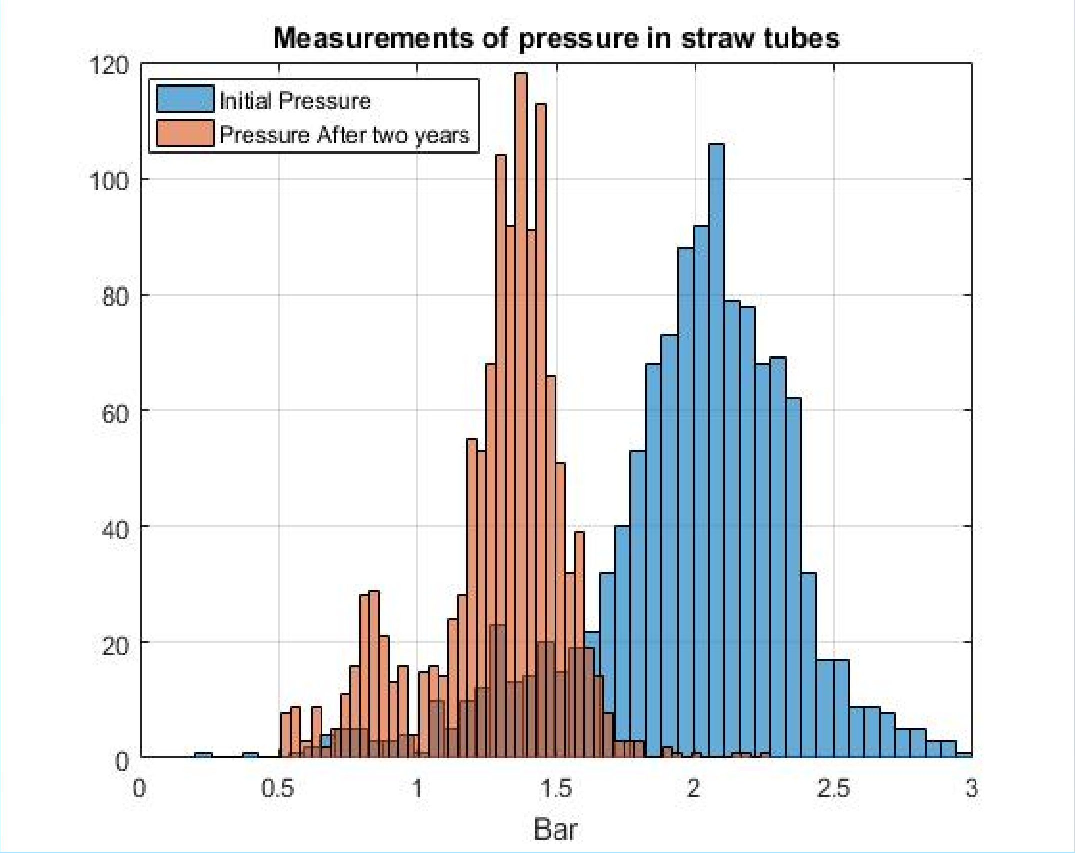
Unit	Diameter	Working pressure	Max pressure
2700	9.8 mm	1 bar	6 bar

J-PARC Clean room in experimental hall

Left: Construction of ready straw tube



Pressure measure device: designed and developed at JINR

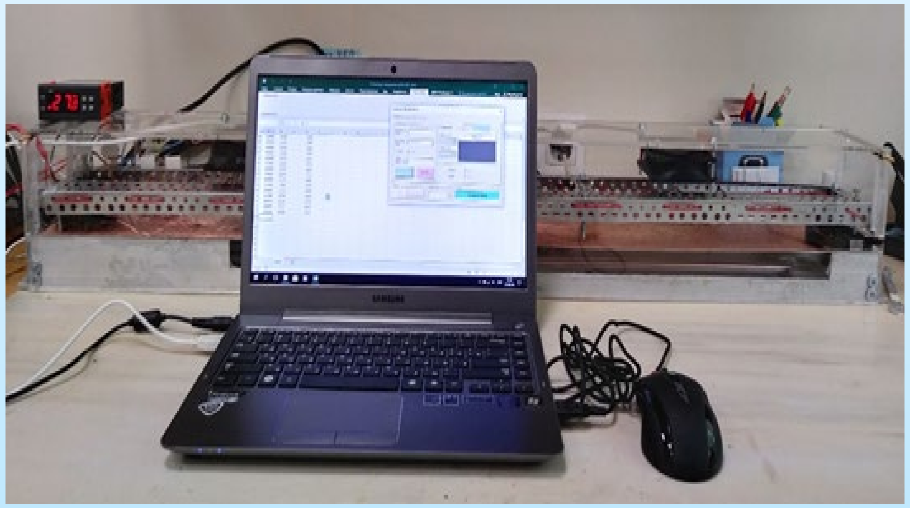


Initial pressure in the tubes and after two years. Pressure loss for 2 years 1 mbar per day.

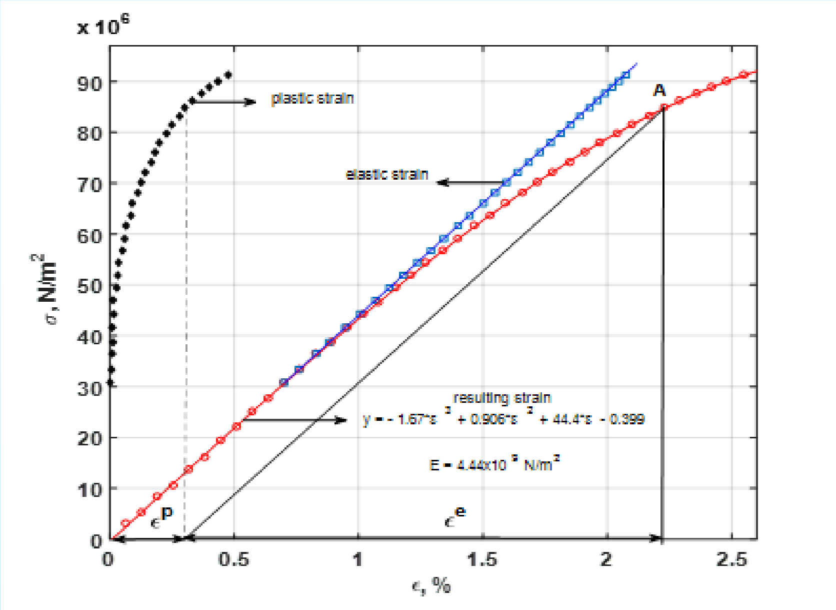
The study of the properties of straws

The following mechanical properties of the 9.8 mm straws have been measured:

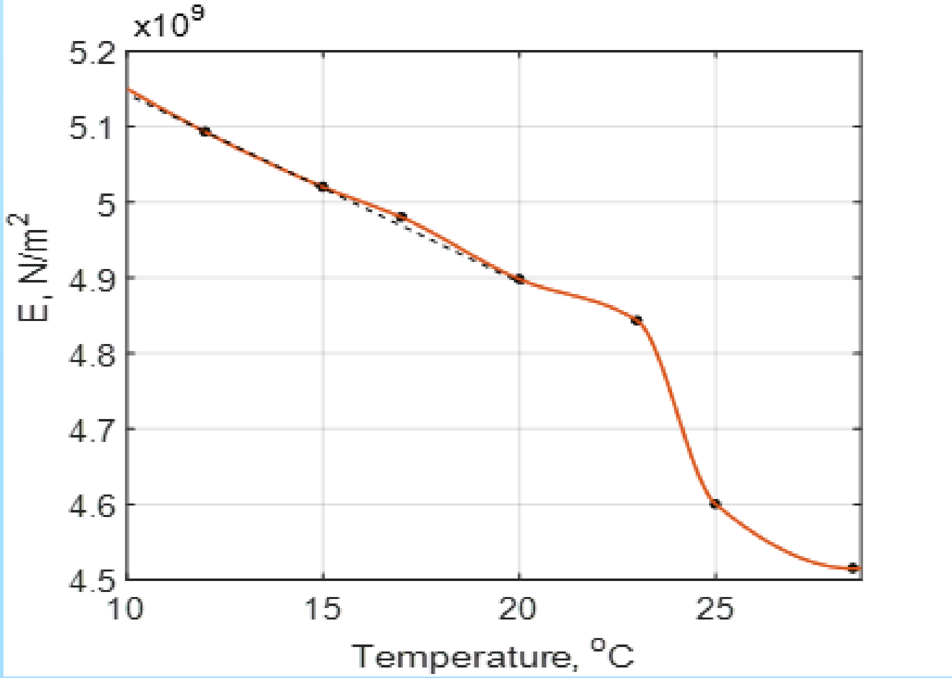
- the range of elastic deformation of the straw
- the influence of temperature and the dependence of the elastic properties of the straw on its thickness
- The tubes aging



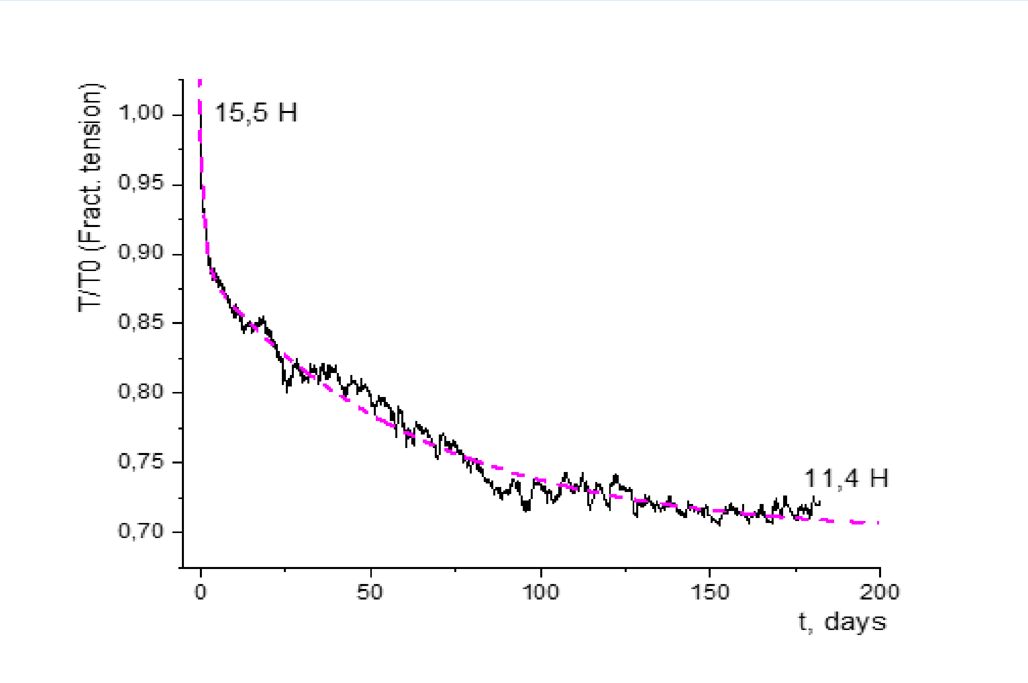
Developed stand's general view



Measurement of the elastic and plastic deformation's area.
The limit value of the straw tension is obtained 1.85kg



The influence of temperature and the dependence of the elastic properties of the straw on its thickness.

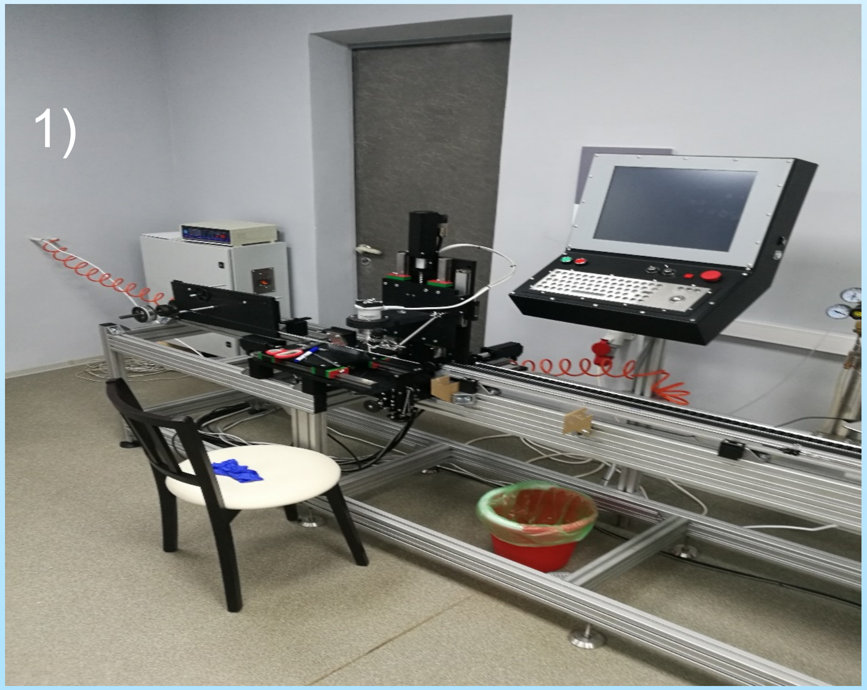


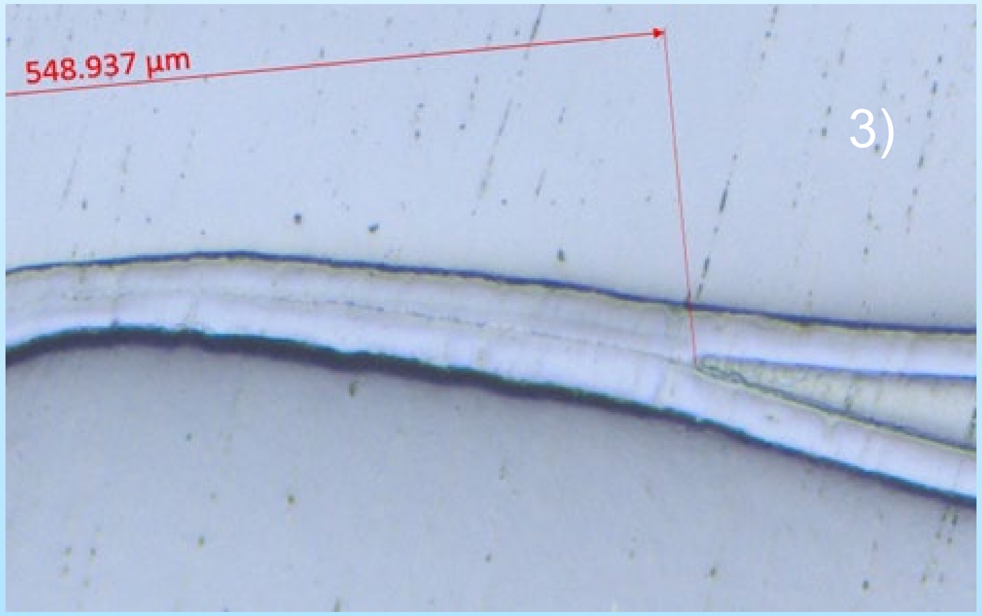
Stress relaxation on time. The service life of straw detector is 9 years.

Also continues the simulation of the straws and studying the straw parameters

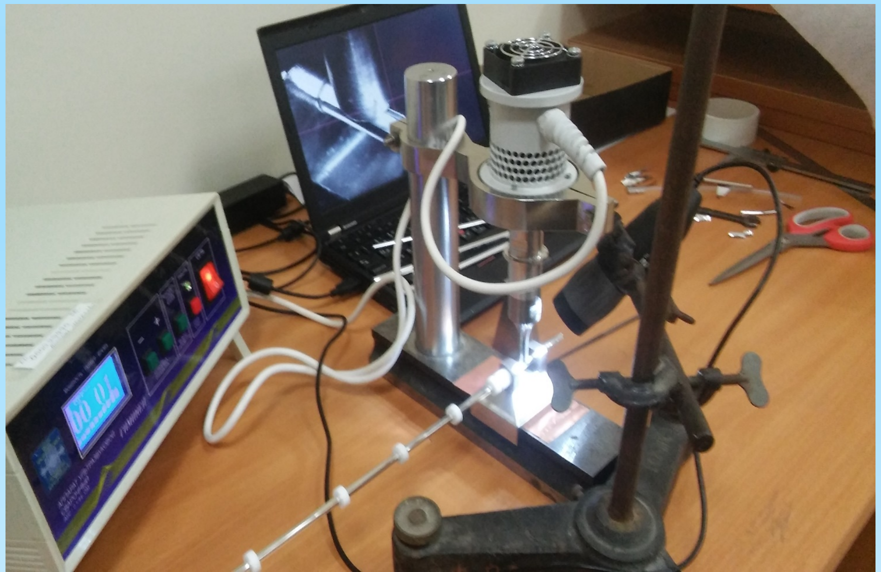
The manufacturing area for straw-tube R&D at DLNP, JINR

Completed real working machine for full dimension 12 μm thickness and 5 mm diameter straw tube production with controllable parameters





High Precision Ultrasonic Welding Machine, for the production of straws tubes



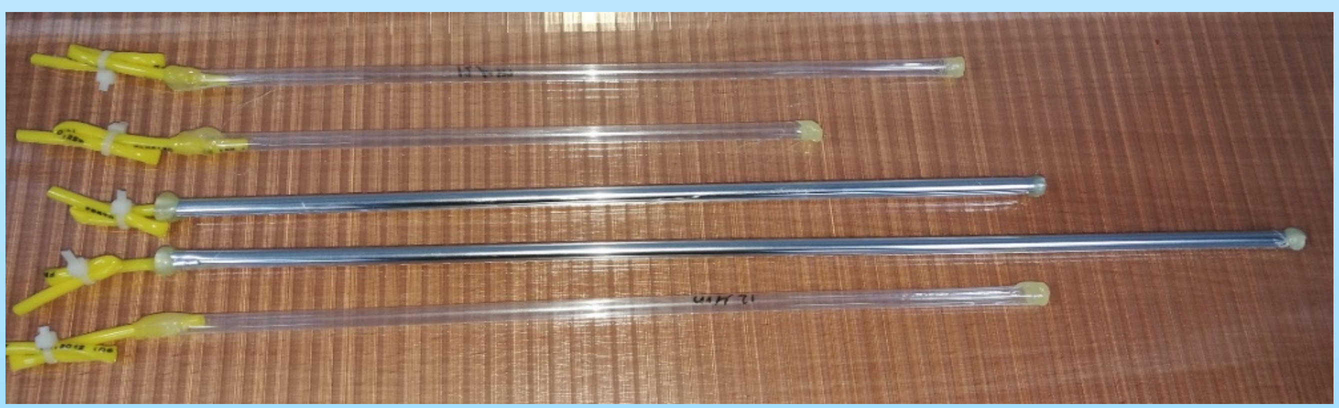
<u>New straw tubes production facility</u>

1) New welding machine design and 5-th class clean room with temperature and humidity control
2) 5 mm diameter and 12 μm wall thickness straw tube
3) Examination of straw Quality control at CERN, Straw tube
4) Study straw tube properties
5) Precise measurements and monitoring of straw diameter with optical methods, accuracy of 0.1 μm

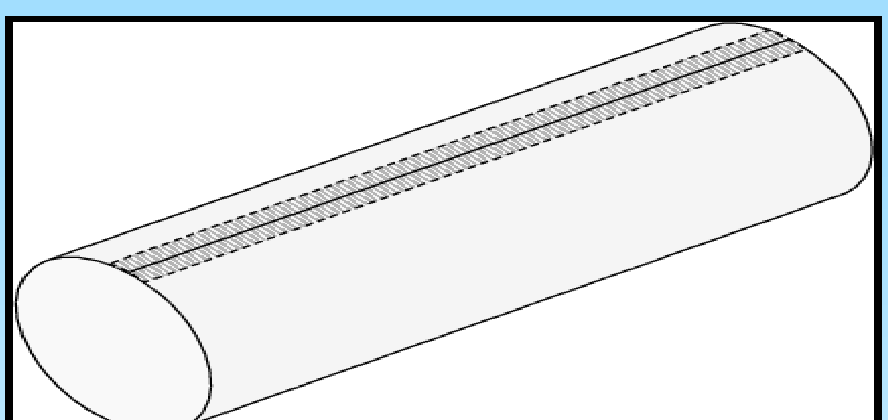
Already have a 5 mm diameter and 12 μm tube

Results and measurements of first in the world ultrathin 12/20 μm thick wall 4.8/9.8 mm diameter straw tubes made by using Ultrasonic welding technology

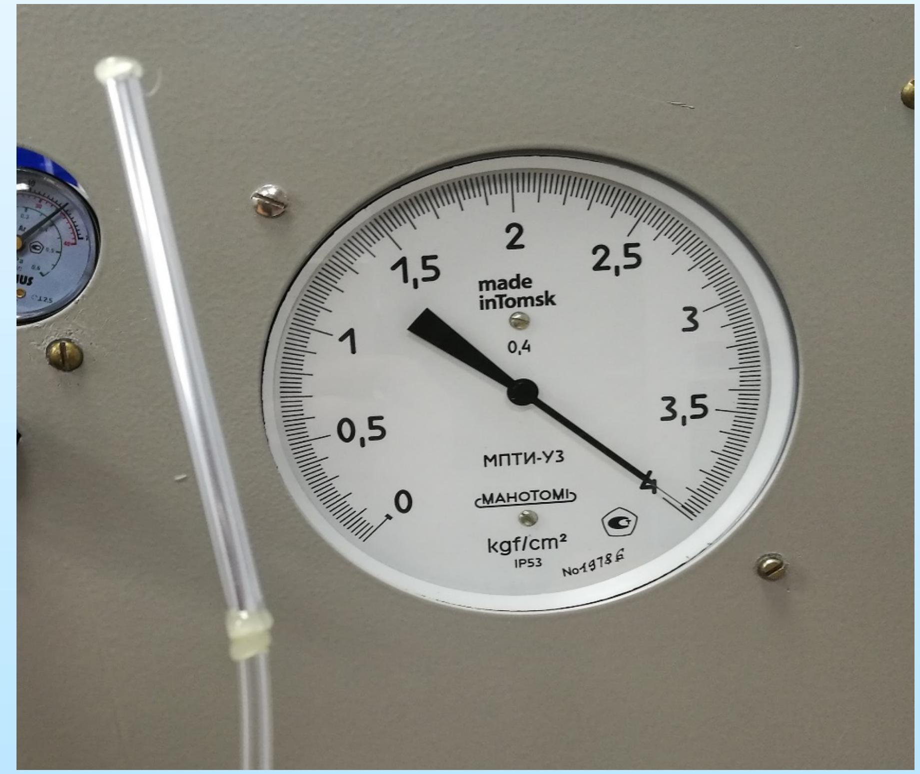
Parameters	20 µm thickness	12 µm thickness
Diameter	9.8±0.04mm	4.8-6 mm
length	1200-1600 mm	50-1600 mm
Test pressure	2 bar absolute	2 bar absolute
Max. pressure	7±1.2 bar absolute	4 ±1 bar absolute
Width of seam	~500 µm	~ 350 µm
Produced amount	2700	



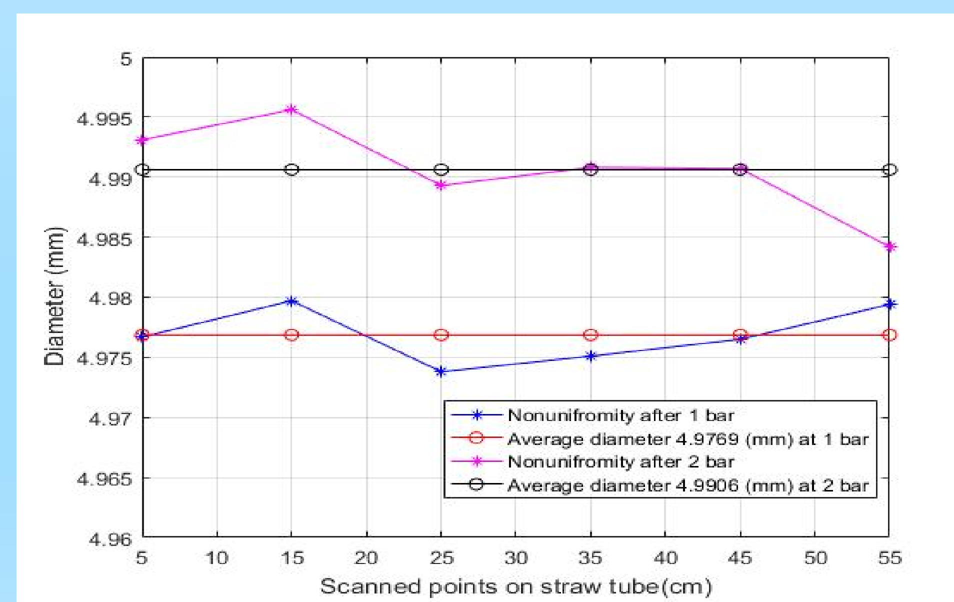
Samples of straw tubes pressurized at 3-4 bar



New design straw, welded by one seam without using glue



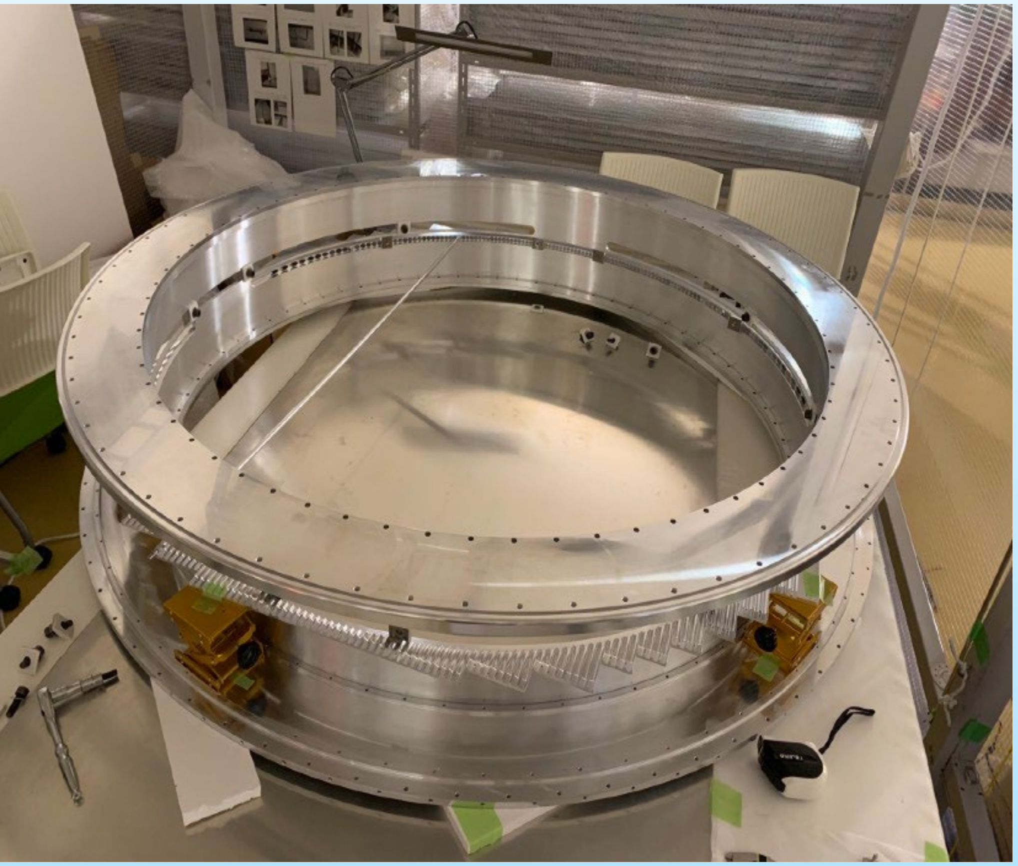
- 4 bar - test pressure before mechanical damage

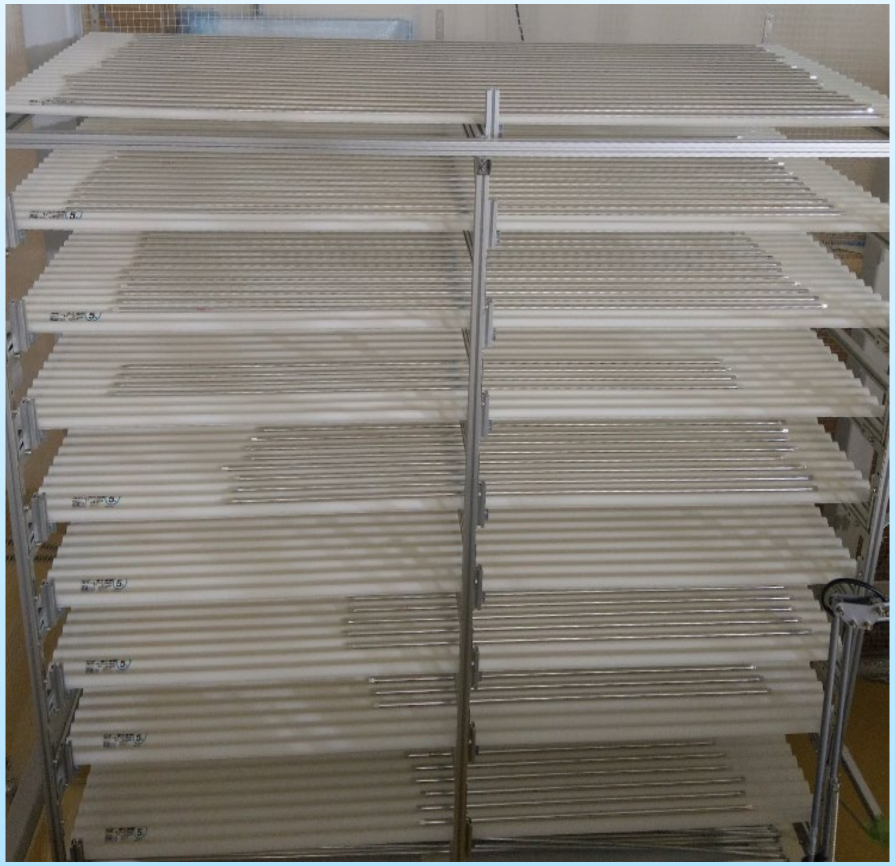


Scanning straw tube with a diameter of 5 mm, a thickness of 12 and 60 cm long

Straw Tracker Status — COMET Phase-I

Assembly for 1st Station is ongoing





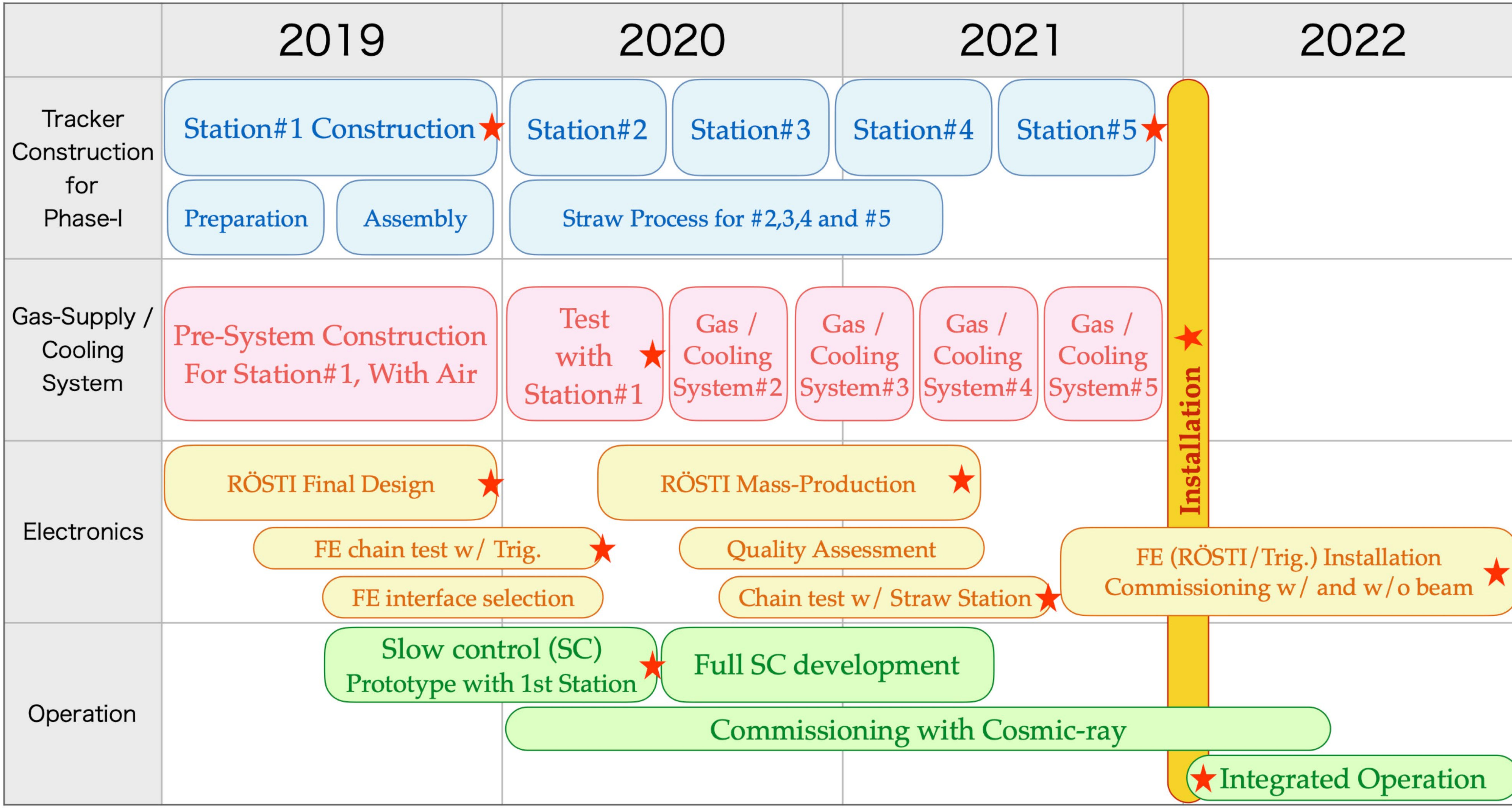
Pressure Vessel, constructed
(with 1straw stretching, without Outer Cylinder)

Straw Process, Ongoing
(cut as a proper length, glued with end-plugs, ready to be stretched)

Taking into account the success of JINR, DLNP COMET group in R&D and production of thin-wall tubes with 5 mm diameters, and development of straw station design,
the COMET collaboration supports the idea of JINR group to use an additional station

with new tubes at Phase-1.

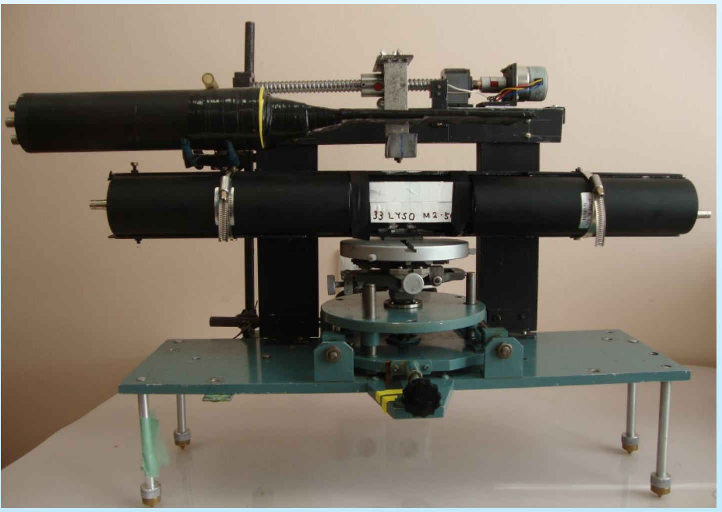
Straw schedule

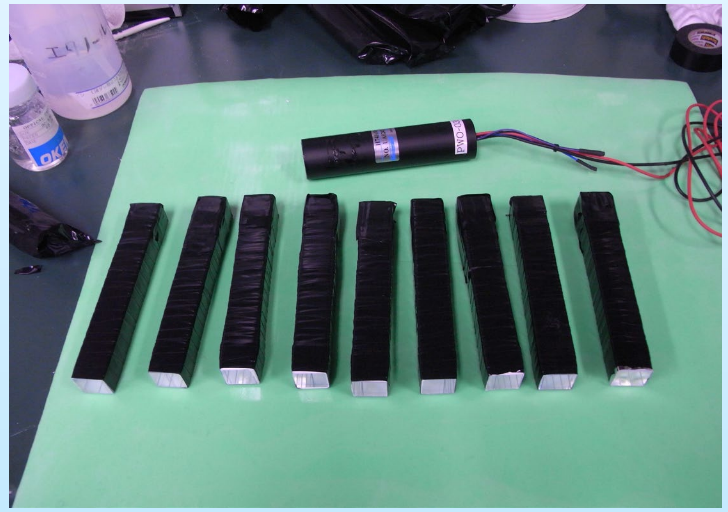


Electromagnetic calorimeter

R&D of LYSO crystals, LYSO crystal parameters investigation

The test bench has been prepared in DLNP





Three candidates vendors

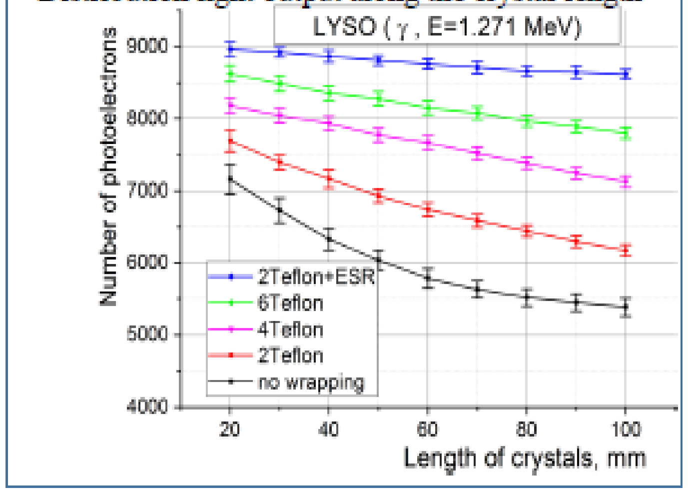
- **Saint-Gobain (SG), Baseline**
- OXIDE (OX), domestic candidate
- Suzhou JT Crystal Technology (JTC)

SG LYSO

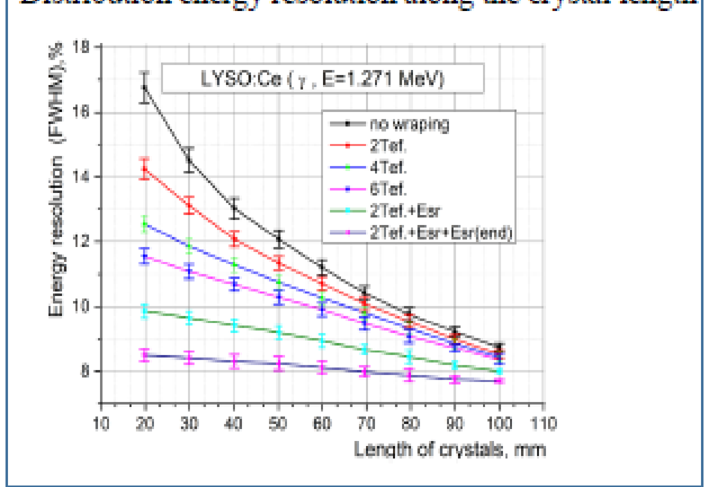
Properties	Standard LYSO	*Enhanced LYSO*
Density [g/cm³]	7.1	
Hygroscopic	no	
Attenuation length for 511keV (cm)	1.2	
Energy resolution [%] @ 511 keV	9.5	8 - 8.5
Wavelength of emission max [nm]	420	
Refractive index @ emission max.	1.81	
Decay time [ns]	45	35
Light yield [photons/MeV]	30000	35000
Average temperature coefficient from 25 to 50° C (%/°C)	-0.28	
Photoelectron yield [% of NaI(Tl)] (for γ-rays)	75	

Optimal wrapping of LYSO:Ce crystal

Distribution light output along the crystal length

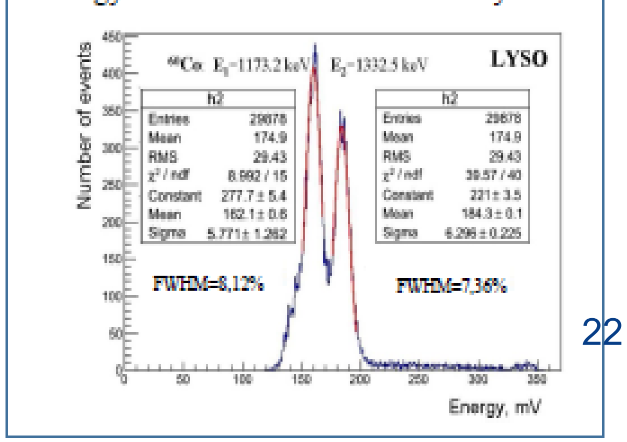


Distribution energy resolution along the crystal length



	Wrapping		Energy resolution (L= 60 mm), [%]
1	Without wrapping	60	11.37
2	2Teflon	74	11.44
3	4Teflon	79	10.59
4	6Teflon	83	9.5
5	2Teflon+ESR	~98,5	8.1

Energy resolution on the center of crystal

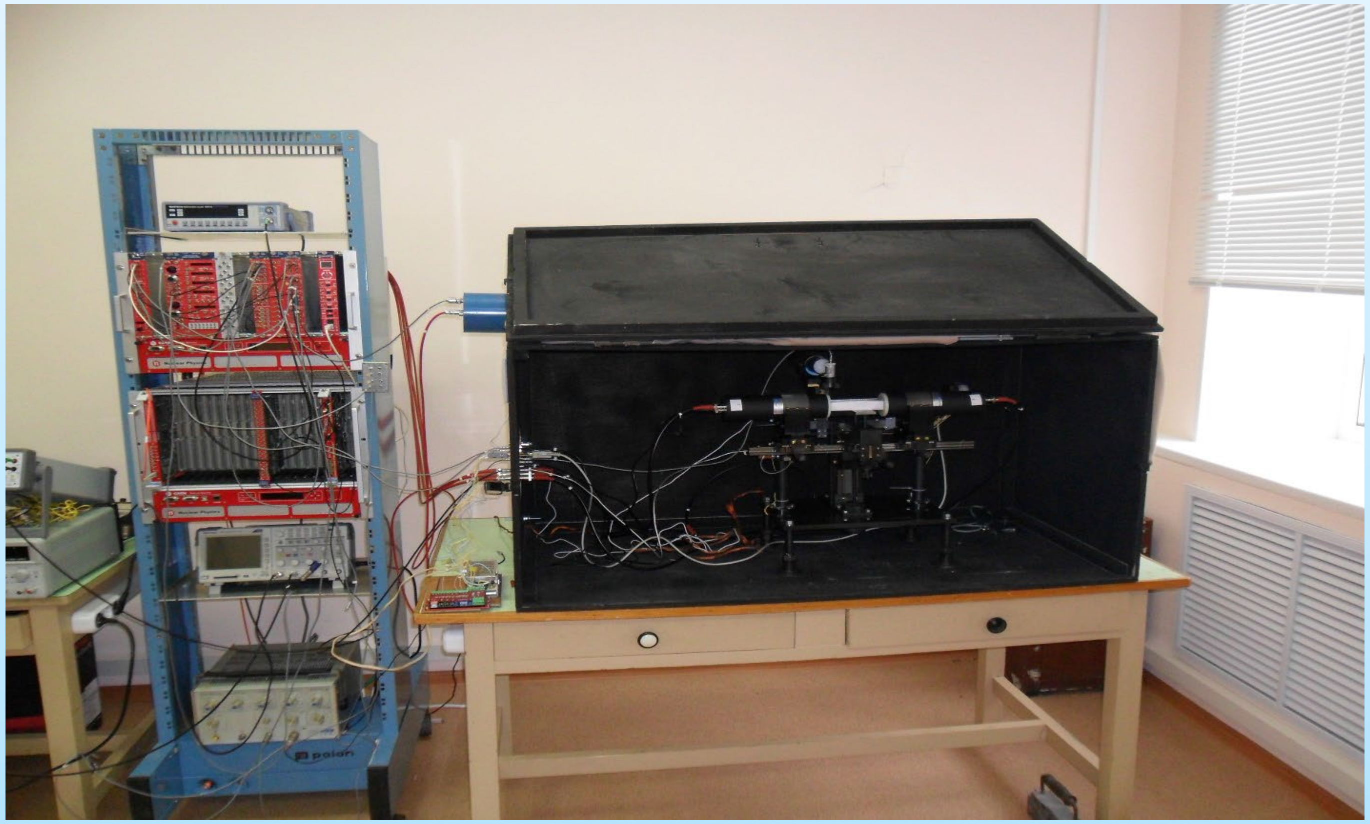


- Simulation of processes in crystals
- Comparison of the crystal types
- Simulation of optimal structure of the calorimeter
- Simulation of the calorimeter geometry in framework ICEDUST
- Experimental study of the main parameters (uniformity, light output) LYSO crystals on a precision JINR stand
- Calibration of 64 crystals of LYSO at the JINR stand for Beam Test (Tohoku)
- Participation in a calorimeter design
- Quality control (certification) of all crystals will be tested in JINR (full responsibility)
- Calorimeter assembling, testing, calibration and installation at setup. (In the near future)

The LYSO crystal certification

A stand was created for certification of the crystals for the COMET calorimeter
Passport for every crystal

- The bench is made of a precision system for moving a radioactive source, a set of detection equipment and a DAQ system.
- The light output and the losses of the light along the crystal length for each crystal are measured.
- About 200 (in total we have more than 300 crystals) were tested. Checking of a new batch of crystals continues.

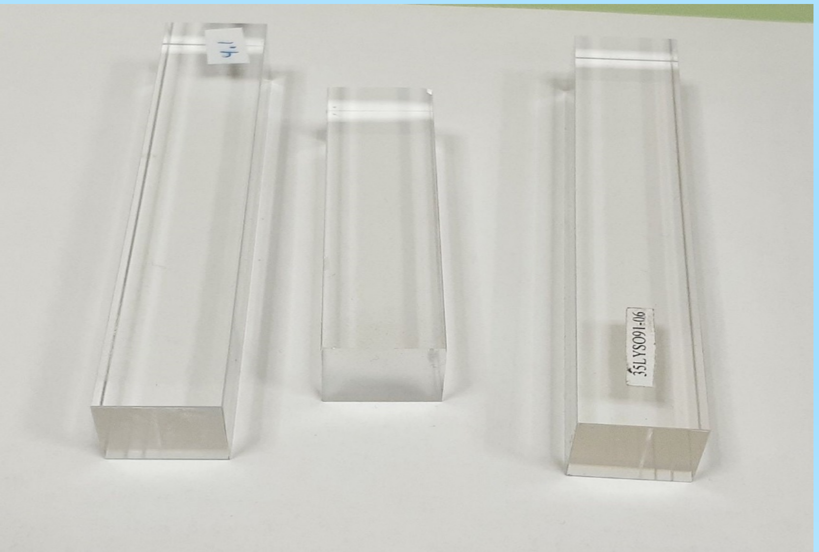


Radiation test 3 crystals

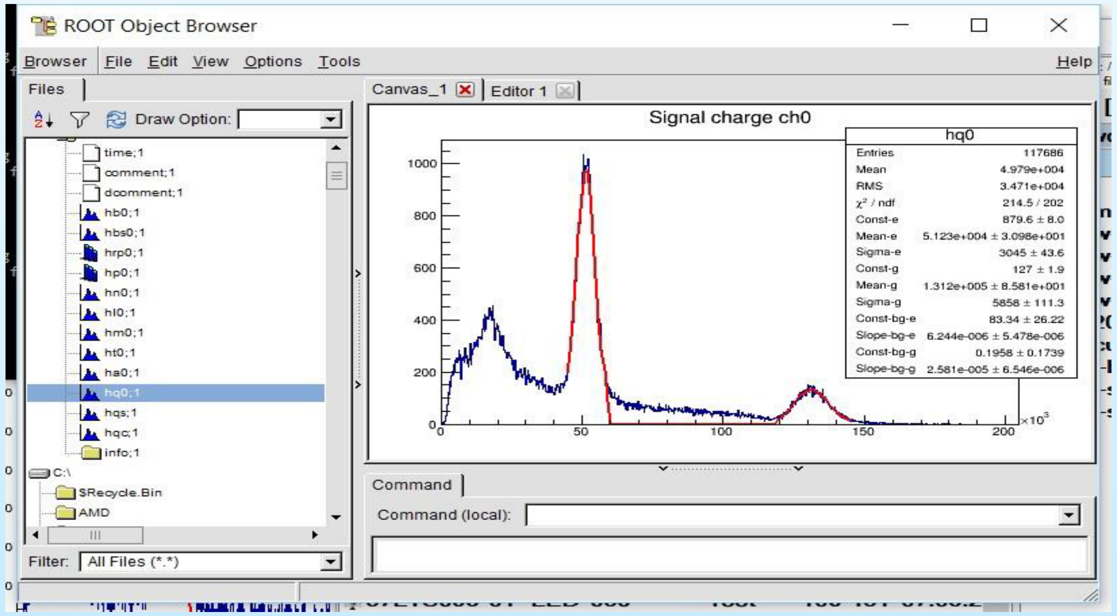
$6 \cdot 10^{11}$ n/cm^2

- Light output increased by about 1.1-1.2 times, but after 3 months returned to almost the initial value.
- Own radioactivity increased from 12 kHz to 30 kHz, but after 3 months fell to 15 kHz.

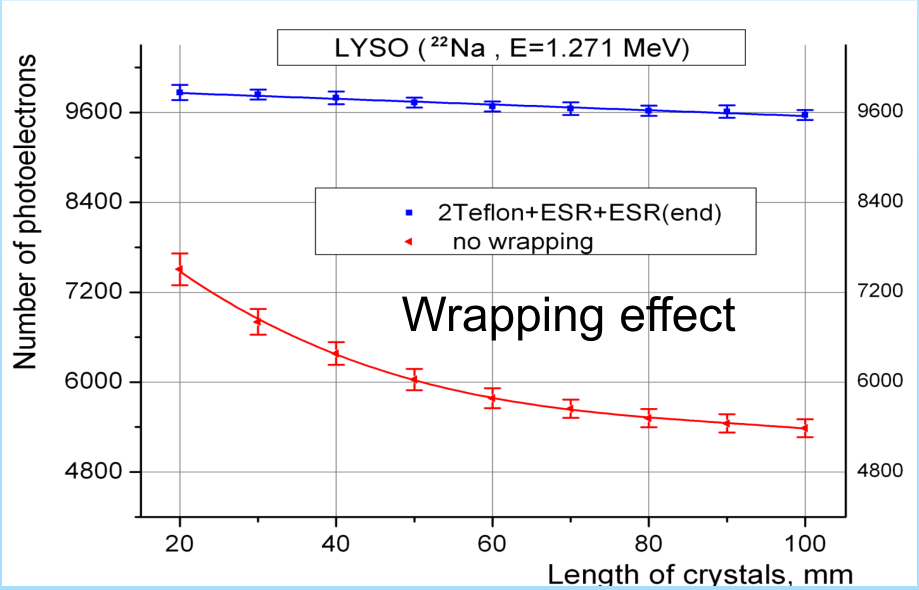
Repeated measurements of irradiated crystals were performed. They confirmed the return of the characteristics to the original ones

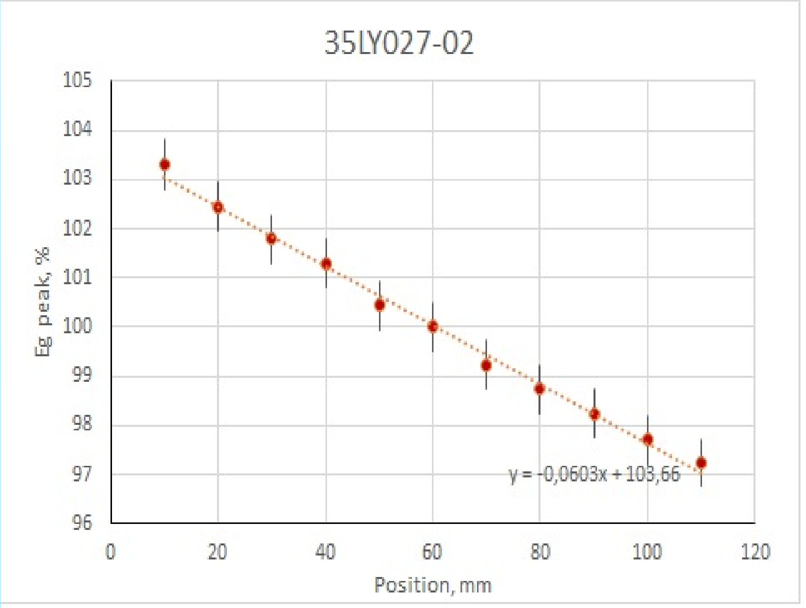


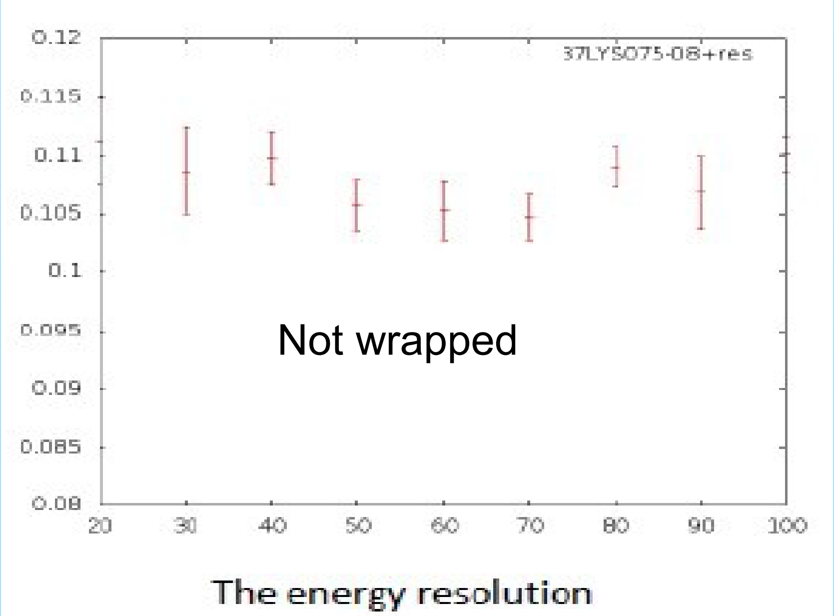
The light output and the losses of the light along the crystal length for each crystal are measured. The data for the crystals are stored in the paper and electronic formats.



The spectrum of Na-22 obtained on one of the crystals

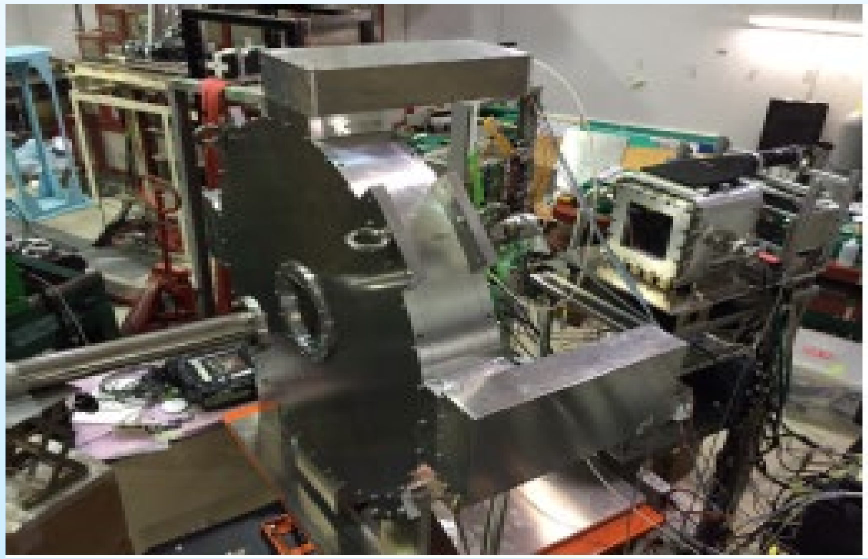




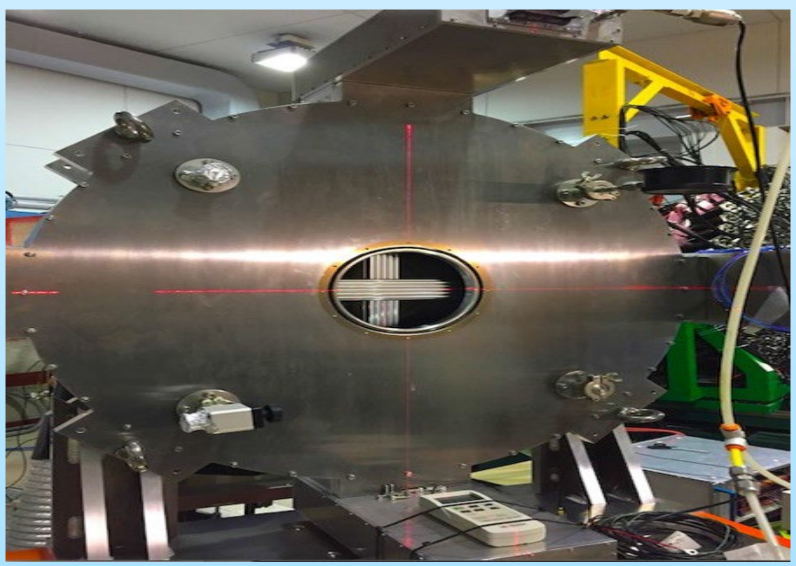


The light attenuation. The example of the losses of light output along the crystal length for two of the LYSO(Ce) crystals. The good crystal 35LYS027-02 has the light attenuation ~0.6 %/cm with good linearity.

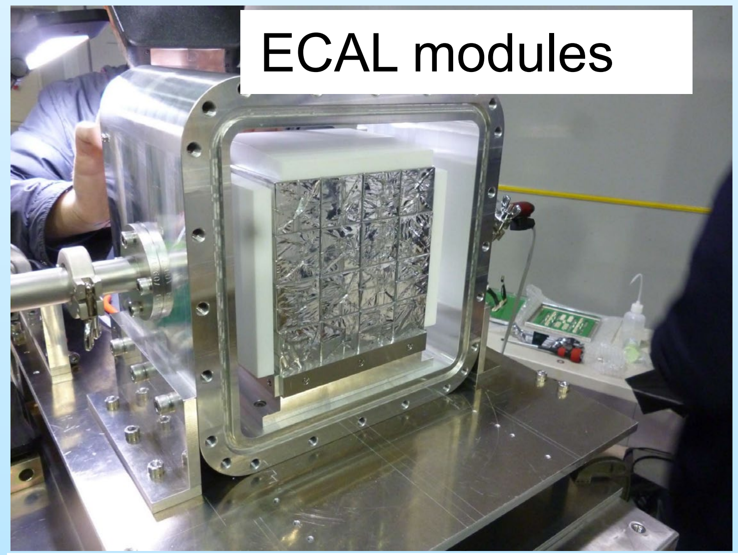
StrECAL system integration tests at ELPH in Tohoku Univ.



- with prototype of Straw tube Tracker and prototype of ECAL
- 100 MeV/c electron beam
- successfully triggered by the ECAL and the electron track was reconstructed with the Straw tube Tracker.
- The prototype of trigger system was tested.



Straw prototype

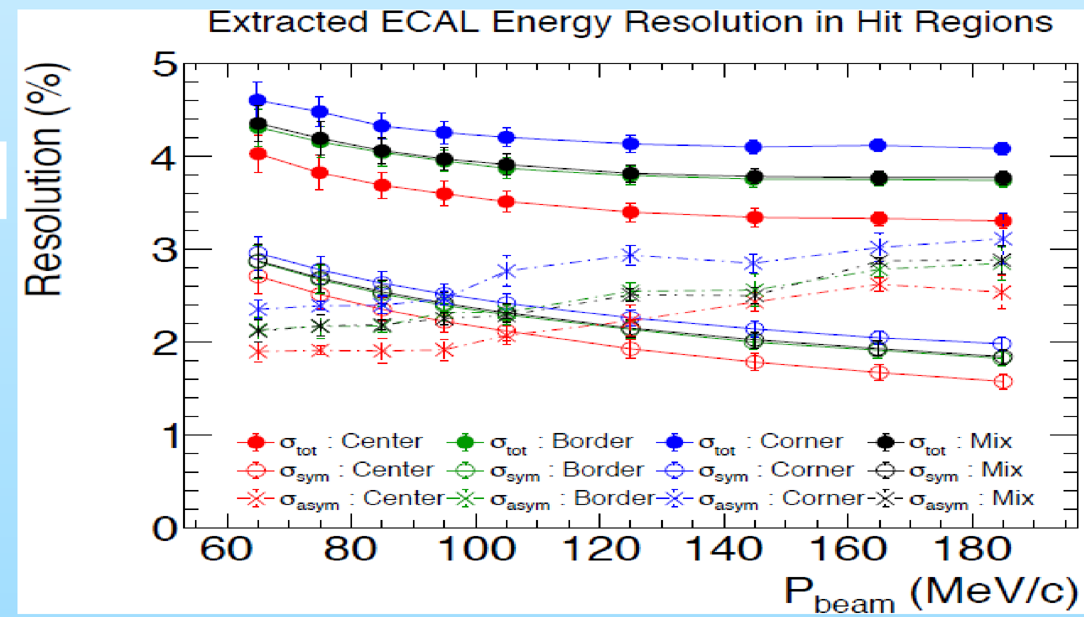


ECAL prototype 64 (8x8) JINR cryst.

The results of straw efficiency and spatial resolution

- **ε > 96%**
- **σ ～100 μm**

Resolution	In 'Mix' Hit Region @ 105 MeV/c
Energy	3.91 ± 0.11 %
(2D)Position	7.66 ± 0.07 mm
Time	0.53 ± 0.05 nsec



Current Status

Straw tube Tracker

- the straw tubes were already mass-produced and checked.
- the 1st station of the straw tracker system has already begun

ECAL

- in the process to purchase ~500-600 LYSO crystal for Phase-I
- the design work for the real detector is also ongoing

Schedule of works on the project in 2021-2023

Straw tracker

- Finalization assembling, testing, installation, cosmic test and calibration of the straw detector for Phase-I, **2021 -2022**
- R&D program for production of the straw tubes of 12 μm wall thickness and 5 mm diameter for Phase-I (about 1000 pcs), production of prototypes and their measurement on beam, **2021 -2022**
- Measuring of all mechanical properties and development of standards for quality control of manufactured of the 5 mm brand-new straw tubes, **2021 -2022**
- Production of a full-scale straw station for Phase-I, with new tubes (12 μm, 5 mm), **2021 - 2022**
- Preparation for mass-production and testing of straw tubes for Phase-II, **2023**

ECAL

- Test (certification) of the crystals in JINR to be used in the calorimeter, **2021-2022**
- Development and optimization of a crystal calibration method for a COMET calorimeter, given the features of the experiment: the presence of a magnetic field and high resolution calorimeter**, 2021 – 2023**

Common task

- Participation in the calorimeter designing, assembling and cosmic test, **2021-2022**
- Participation in assembling, testing and installation of whole detector system for Phase-I, **2021-2023**
- Complex detector system (tracker, calorimeter, etc.) simulation, **2021 - 2022**
- Participation in the engineering and physics run for Phase-I**, 2022-2023**
- Participation in the data acquisition and analysis, **2022-2023**
- Participation in the beam tests of the detector components for Phase II, **2021 -2023**

Estimation of human resources

Name	FTE	Positon	Work (apart common duties like shifts)
G. Adamov	0.7	Junior researcher PhD student	Software tools development, analysis
D. Aznabayev	0.2	Junior researcher PhD student	Theoretical issues, physics analysis
D. Baygarashev	0.2	Junior researcher PhD student	Data quality control, calibration, physics analysis
V.N. Duginov	0.5	Head of sector	Calorimeter development, analysis
T.L. Enik	0.2	Head of sector	Hardware development and support
K.I. Gritsai	0.2	Senior scientist	Software tools development
I.L. Evtoukhovitch	0.7	Senior engineer	Hardware support
P.G. Evtoukhovitch	1.0	Senior scientist	Hardware development and support
V.A. Kalinnikov	0.9	Leading scientist	Calorimeter development, MC, analysis
E.S. Kaneva	1.0	Engineer	MC development, analysis
X. Khubashvili	0.7	Engineer	Hardware support
A. Khvedelidze	0.3	Leading scientist	Theoretical issues, models development
A. Kobey	0.5	Master student	Calorimeter development, MC, analysis
G.A. Kozlov	0.2	Leading scientist	Theoretical issues, models development
M.D. Kravchenko	1.0	Junior researcher PhD student	Hardware development, data quality control, analysis
A.S. Moiseenko	1.0	Scientist	Hardware development and support
A. Issadykov	0.2	Senior scientist	Theoretical issues, physics analysis
A.V. Pavlov	1.0	Junior researcher PhD student	MC, Data quality control, physics analysis
B.M. Sabirov	1.0	Scientist	Hardware development and support
A.G. Samartsev	0.2	Senior engineer	Hardware development, detector design
Z. Tsamalaidze	0.7	Head of sector	Project leader
N. Tsverava	1.0	Junior researcher PhD student	Hardware development, calibration, analysis
E.P. Velicheva	1.0	Senior scientist	Calorimeter development, MC, analysis
A.D. Volkov	1.0	Scientist	Hardware development
Total FTE	15.4		

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2. V. Kalinnikov, E. Velicheva. Research of the ECAL calorimeter used in the COMET experiment. // Functional Materials, 22 (2015), 1, 116-125.
3. V. Kalinnikov, E. Velicheva. Research of long GSO and LYSO crystals used in the calorimeter developed for the COMET experiment. Functional Materials, 22 (2015), 1, 126-134.
4. V. Kalinnikov, E. Velicheva. Simulation of Long GSO Crystals for the COMET Experiment. // Nonlinear Phenomena in Complex. V. 8, No 2 (2015). Pp. 215 – 221.
5. В. Калинников, Е. Величева, А. Лобко. Исследование длинных кристаллов GSO и LYSO для создания сегментированных электромагнитных калориметров. Физика сцинтилляторов. Материалы, методы, аппаратура. Изд: ИСМА . 2015. С. 137-158 .
6. Калинников В. Величева Е. Исследование параметров и разработка алгоритма пространственной реконструкции для калориметра COMET эксперимента. Изд:ИСМА . 2015. С. 186-203.
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9. V. Kalinnikov, E. Velicheva. Simulation of Long GSO Crystals for the COMET Experiment. NONLINEAR PHENOMENA IN COMPLEX SYSTEMS, 18, №2, 215 (2015).
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11. A.D. Volkov. Wire tension monitor for proportional chambers of the ANKE spectrometer. NIM A 701, 80 (2013).
12. A.D. Volkov et all. Influence of internal pressure on stress of welded straws of track detectors. Uspekhi prikladnoi phiziki, 2018, v 6, № 1, p. 83 – 90, in Russian
13. A.D. Volkov *et all.* The test bench for studying the characteristics of straw tubes. Preprint JINR E13-2018-70
14. Волков А. Д., Кравченко М. Д., Павлов А. В. Стенд для исследования характеристик строу. Успехи прикладной физики, 2019, т. 7, №1, С. 76-84
15. А.Д. Волков. Устройство для измерения натяжения трубки в строу детекторах. Патент 2539107 (2013).
16. Волков А.Д., Кравченко М.Д., Павлов А.В. Устройство для исследования свойств строу трубки координатного детектора частиц. Патент 2691770 (2019)
17. N. Tsverava et al. Thin-wall straw tubes for experiment COMET (in preparation).

18. COMET Phase-I. Technical Design Report 2018 (prepared with participation of the JINR physicists).
19. H. Nishiguchi, P. Evtoukhovitch, A. Moiseenko, Z. Tsamalaidze, N. Tsverava, A. Volkov, et al. Development of an extremely thin-wall straw tracker operational in vacuum- The COMET straw tracker system. Accepted NIM, V845, 2017. Pages 269-272
20. Kazuki Ueno, Peter Evtoukhovitch, Anatoly Moiseenko, Eitaro Hamada, Takashi Saito, Nikolozi Tsverava, Kou Oishi, Alexander Samartsev, Hajime Nishiguchi, Zviadi Tsamalaidze Development of a thin-wall straw-tube tracker for COMET experiment. **Po**S EPS-HEP2017 (2017) 524
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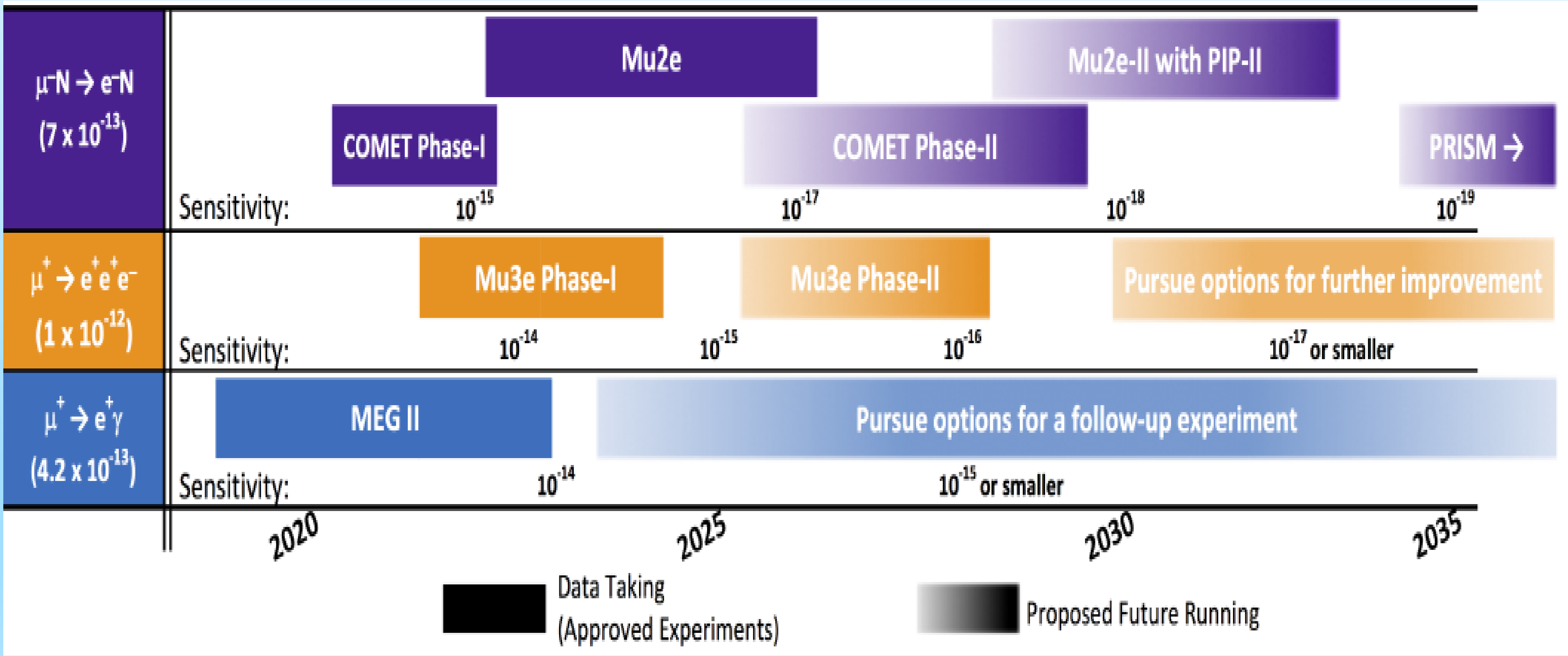
22. H. Nishiguchi, P. Evtoukhovitch, A. Moiseenko, Z. Tsamalaidze, N. Tsverava, A. Volkov, et al. Construction on vacuum-compatible straw tracker for COMET Phase-I. Accepted NIM, 2019.

CLFV Schedule in the near future

Searches of Charged-Lepton Flavor Violation in Experiments using Intense Muon Beams



Summary

- The COMET is a search experiment for μ-e conversion at J-PARC
  - aiming improvement the sensitivity x 10,000 better than the past limit, $1.0 \cdot 10^{-17}$
  - staging approach called Phase-I (under construction) / Phase-II
- **COMET Phase-I** is now under construction
  - aiming improvement the sensitivity x 100 better than the past

Phase-I Goal:
(in 150 days operation)

$$B(\mu^- + Al \rightarrow e^- + Al) = 3.0 \times 10^{-15} \text{ (S.E.S)}$$
$$B(\mu^- + Al \rightarrow e^- + Al) < 7 \times 10^{-15} \quad (90\% C.L.)$$

Up to 10^{-15} → sensitive to "new physics"

- CDC detector for physics search is under construction now
- the other system is also under construction
- We plan to be **ready in 2022.**

- In parallel preparation and carrying out Phase-I, will go work on creation of a full muon bunch, R&D for COMET Phase-II is underway. After completion of Phase-I, will immediately begin installation and assembly for Phase-II. Expecting to start in 202X?
- JINR plays a visible role in preparation of this experiment of fundamental importance.

Estimation of costs and resources

Proposal for resources necessary for realization of the project "Search for coherent neutrino-less μ -e conversion at J-PARC (COMET) ", 2021-2023

Form №26

Units and systems of The setup, resources, Sources of financing			Cost of units (k$). Required resources	Laboratory proposal for schedule of financing and resources		
				1 year	2 year	3 year
Main items	Computers Electronic devices Materials		30 120 180	10 400 60	10 40 60	10 400 60
Resources	Hours	Design bureau DLNP Workshop	800 hours 1200 hours	300 500	300 500	200 200
Source of financing	Budget	Budget expenses (without salary)	660	220	220	220
	Non-budget	Grant of the Plenipotentiary of Georgia	30	10	10	10
		Program of the JINR-Belarus Co-operation.	15	5	5	5
		Grant of the Plenipotentiary of Kazakhstan	30	10	10	10

Form №29

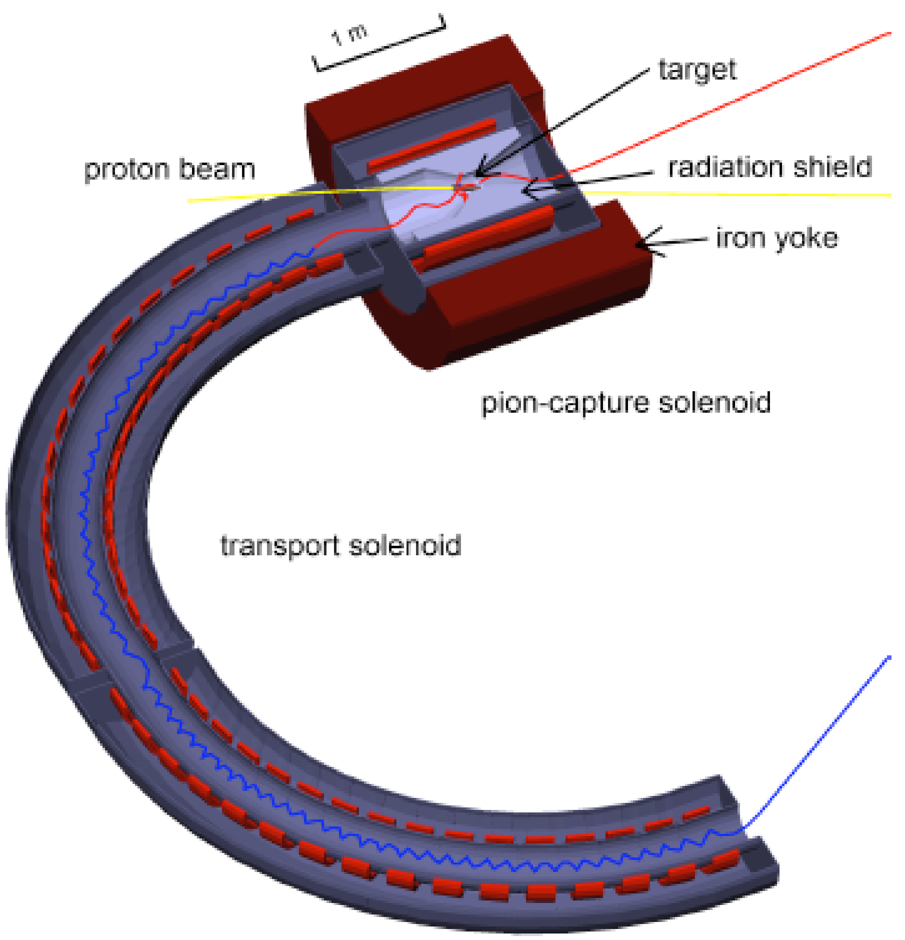
NN	Purpose of expenses from DLNP	Full cost	1st year	2nd year	3rd year
	Direct expenses				
1.	Accelerator	-	-	-	-
2.	Computing	-	-	-	-
3.	Design bureau	800 hours	300	300	200
4.	Workshop LNP	1200 hours	500	500	200
5.	Materials	180 k$	60	60	60
6.	Equipment	150 k$	50	50	50
7.	COMET operation fee	60 $	20	20	20
8.	Business trips:				
	a) To the non-rouble zone countries	255 k$	85	85	85
	b) To the cities of rouble zone countries	15 k$	5	5	5

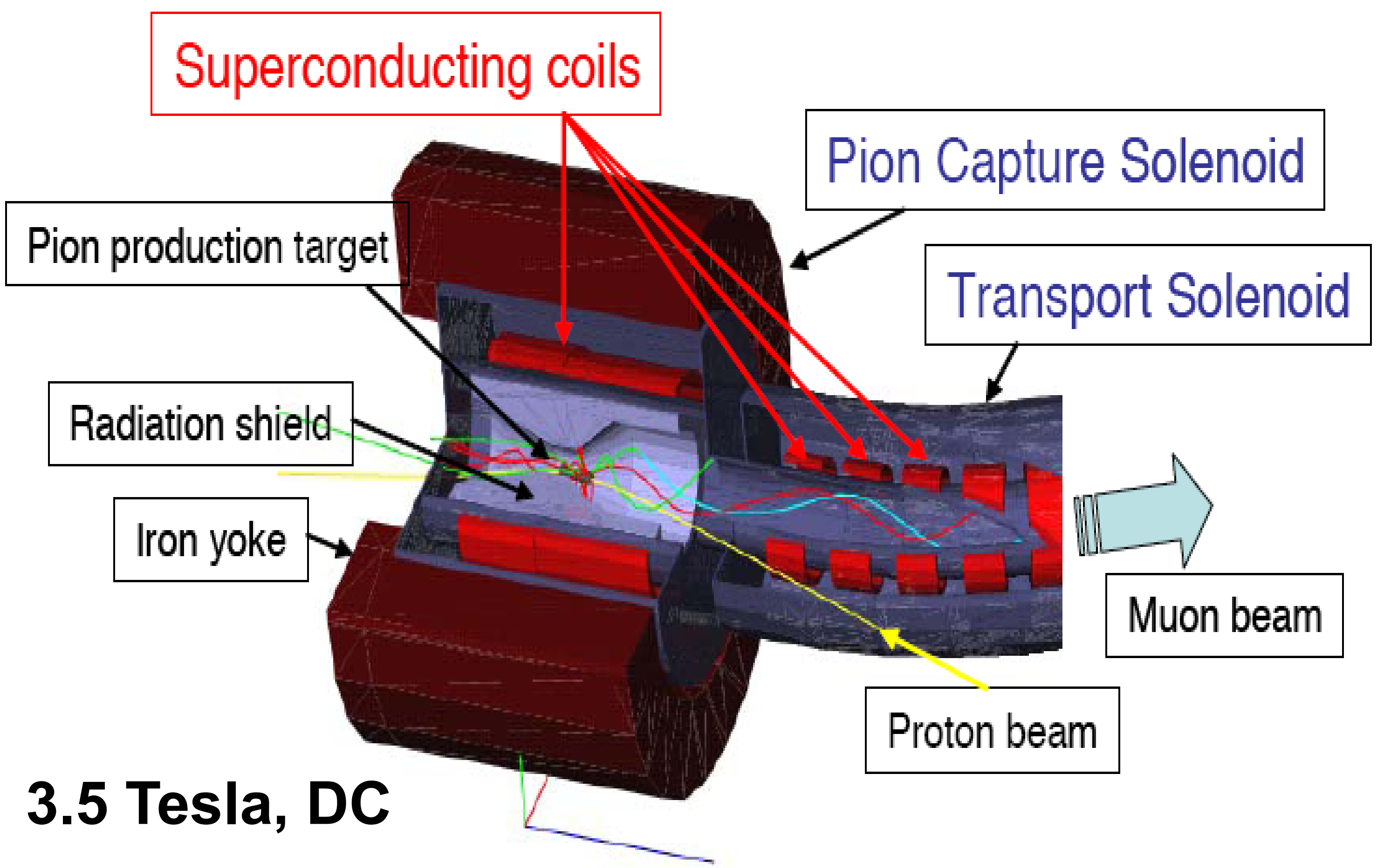
Thank you for attention!

BACKUP

Demonstration of the Pion Capture System for COMET

It is very important that this is experimental confirmation

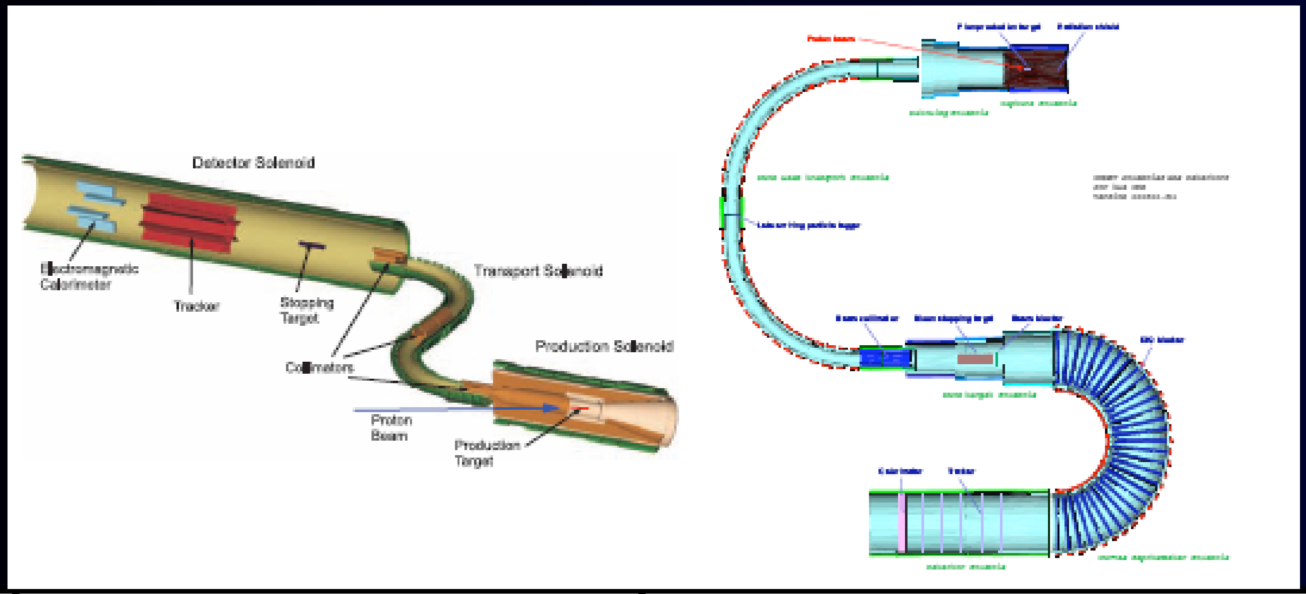




A muon beam intensity of 10^8 muons/sec with a proton beam of 400MeV energy with 1μA beam current from the RCNP proton ring cyclotron.
This beam intensity is almost the same as in PSI.
10^{-4} muons/proton/GEV for MUSIC, RCNP
10^{-7} muons/proton/GEV for PSI
The muon production efficiency per proton is about 1000

Mu2e vs. COMET

2021 or 2022



2018-2019 Phase-I

	Mu2e	COMET
muon beamline	S-shape	C-shape
electron spectrometer	Straight solenoid	Curved solenoid

better selection of low momentum muons

eliminate muon decay in flight

better selection of 100 MeV electrons

eliminate protons from nuclear muon capture.

eliminate low energy junk events to make the detector quiet.

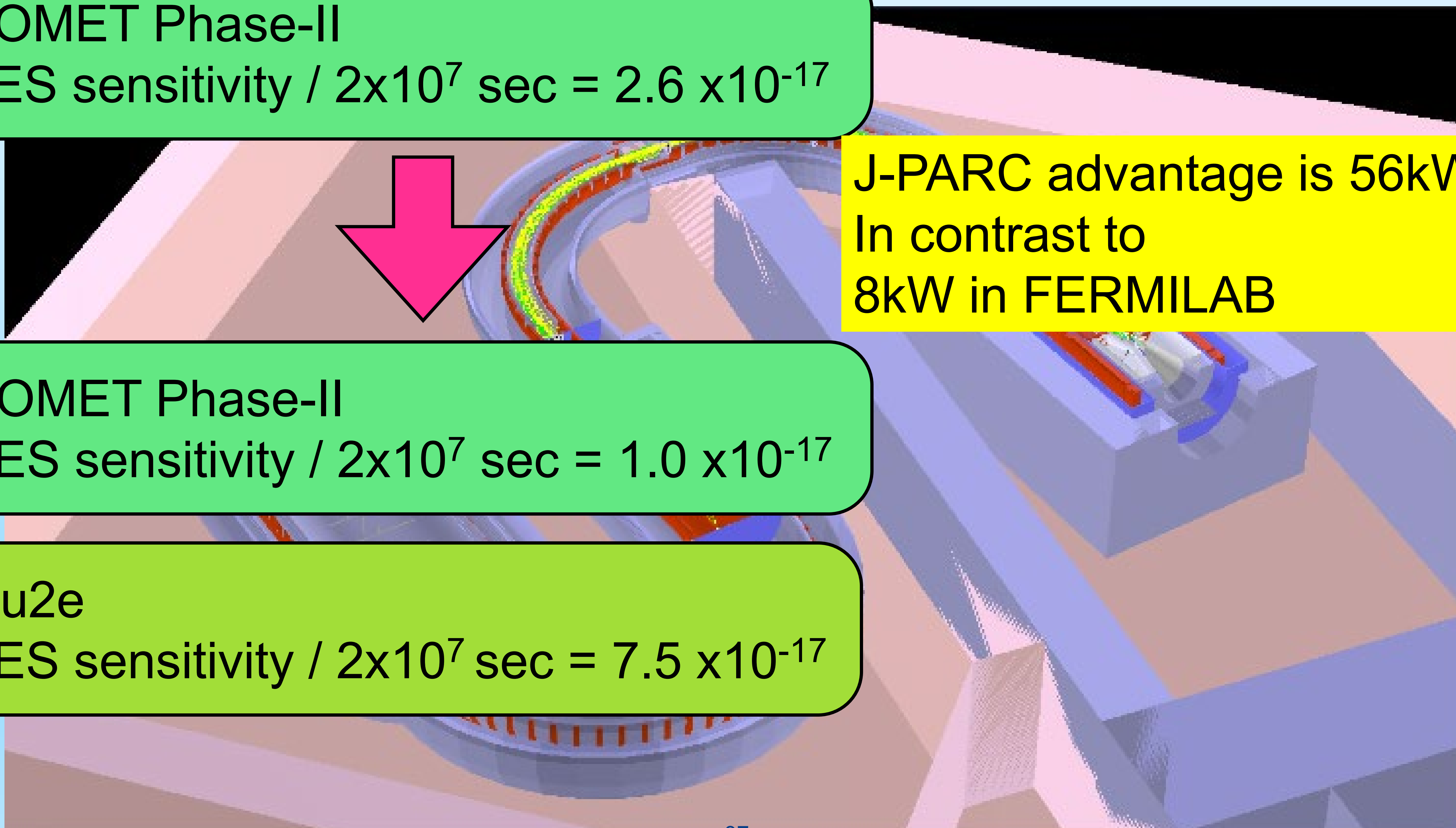
ICEDUST Study on COMET Phase-II

COMET Phase-II
SES sensitivity / 2×10^{7} sec = 2.6×10^{-17}

COMET Phase-II
SES sensitivity / 2×10^{7} sec = 1.0×10^{-17}

Mu2e
SES sensitivity / 2×10^{7} sec = 7.5×10^{-17}

J-PARC advantage is 56kW
In contrast to
8kW in FERMILAB



Detector single rate: tracker and calorimeter

	Timing	Tracker (kHz)	Calorimeter (kHz)	Energy (MeV)
DIO electrons	Delayed	10	10	50–60
Back-scattering electrons	Delayed	15	200	< 40
Beam flash muons	Prompt	$< 150^{\ddagger}$	$< 150^{\ddagger}$	15–35
Muon decay in calorimeter	Delayed	—	$< 150^{\ddagger}$	< 55
DIO from outside of target	Delayed	< 300	< 300	< 50
Proton from muon capture	Delayed	—	—	—
Neutron from muon capture	Delayed	—	10	~ 1
Photons from DIO e^- scattering	Delayed	150	9000	$\langle E \rangle = 1$

Comparison of Phase-I and Phase-II parameters

Parameters	Phase-I	Phase-II
Beam power	3.2 kW (8 GeV)	56 kW (8 GeV)
Running time	150 days	1 year
Target materials	graphite	tungsten
#protons	2.37×10^{19}	8.5×10^{20}
#muon stops (N_μ)	1.5×10^{16}	2.0×10^{18}
Muon rate/s	5.8×10^{9}	1.0×10^{11}
#muon stops/proton	0.00052	0.00052
#BG events	0.032	0.34
The detector acceptance ($A_{\mu\text{-}e}$)	0.041	0.04
S.E.S (single event sensitivity)	**3.1×10^{-15}**	**2.6×10^{-17}**
U.L. (upper limit, 90%CL)	**$< 7.2 \times 10^{-15}$**	**$< 6.0 \times 10^{-17}$**
Measurement start	**2018-2019**	**2021**

ICEDUST Study on COMET Phase-II

COMET Phase-II
SES sensitivity / 2×10^{7} sec = 1.0×10^{-17}