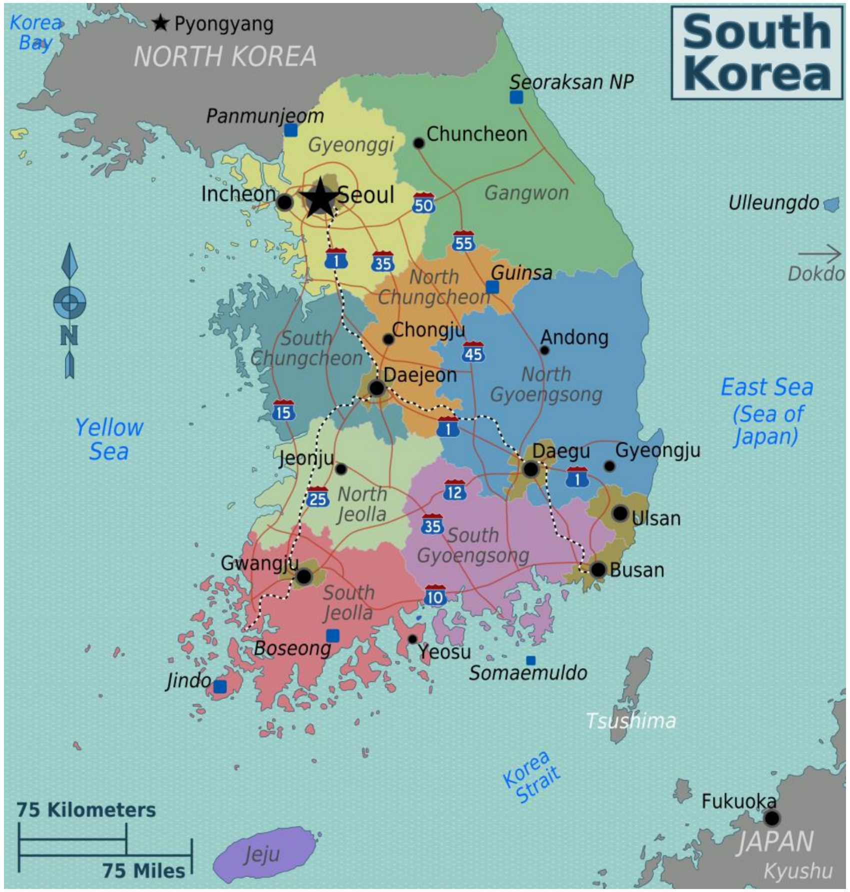
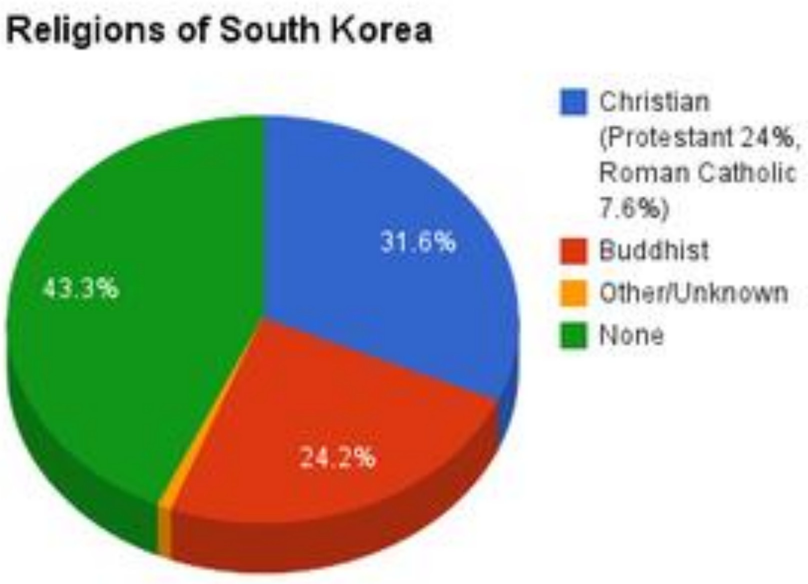
KOMAC accelerator facility (Korea): precise out-vacuum proton beam monitoring system based on vibrating wire





General information

- The current population of **the Republic of Korea** is **50,477,022** as of Sunday, May 15, 2016, based on the latest United Nations estimates.
- The population density in South Korea is 519 per Km^2
- The total land area is 97,235 Km^2
- **81.6 %** of the population is **urban** (41,275,898 people in 2016)
- The **median age** in South Korea is **41.1 years**.

General information

The Korean Alphabet

Vowels	ㅏ	ㅑ	ㅓ	ㅕ	ㅗ	ㅛ	ㅜ	ㅠ	ㅡ	ㅣ
	a	ya	ŏ	yŏ	o	yo	u	yu	ŭ	i

Consonants	ㄱ	ㄴ	ㄷ	ㄹ	ㅁ	ㅂ	ㅅ
	k, g	n	t, d	r, l	m	p, b	s, sh
	ㅇ	ㅈ	ㅊ	ㅋ	ㅌ	ㅍ	ㅎ
		ch, j	ch'	k'	t'	p'	h

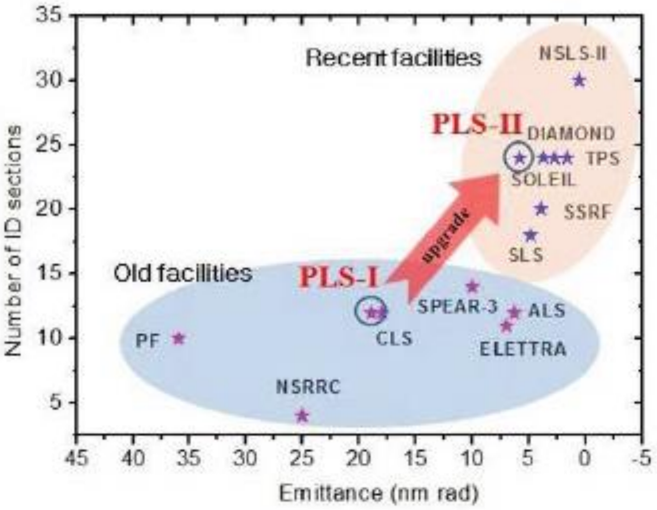
General information

Доля затрат на науку в ВВП в России не понималась выше отметки 1,2% при критическом пороговом значении этого показателя в 1,5%. Заложенные параметры затрат на науку в ВВП, которые должны достигнуть уровня 1,73% только к 2030−2035 годам, практически делают невозможным не только сокращение технологического отставания, но и приведут к его дальнейшему росту. Следует отметить, что уже сегодня затраты на науку в ВВП достигли в США 2,73%, в Германии — 2,85%, во Франции — 2,23%, в Японии — 3,46%, в Израиле — 4,21%, в Китае — 1,98%, Южной Корее — 4,36%.

Елена Ленчук, 4 Июня 2016, 00:16 — **REGNUM**

PAL-PLS

Pohang Accelerator Laboratory (PAL) was established in 1988.
Pohang Light Source (PLS) became the 5th third-generation light source in the world. It has been successfully operated since its initial service in 1995.



Ki Bong Lee, director PAL
kibong@postech.ac.kr

PLS-II upgrade-project has been carried out from Jan '09 to Dec'11

PAL-PLS

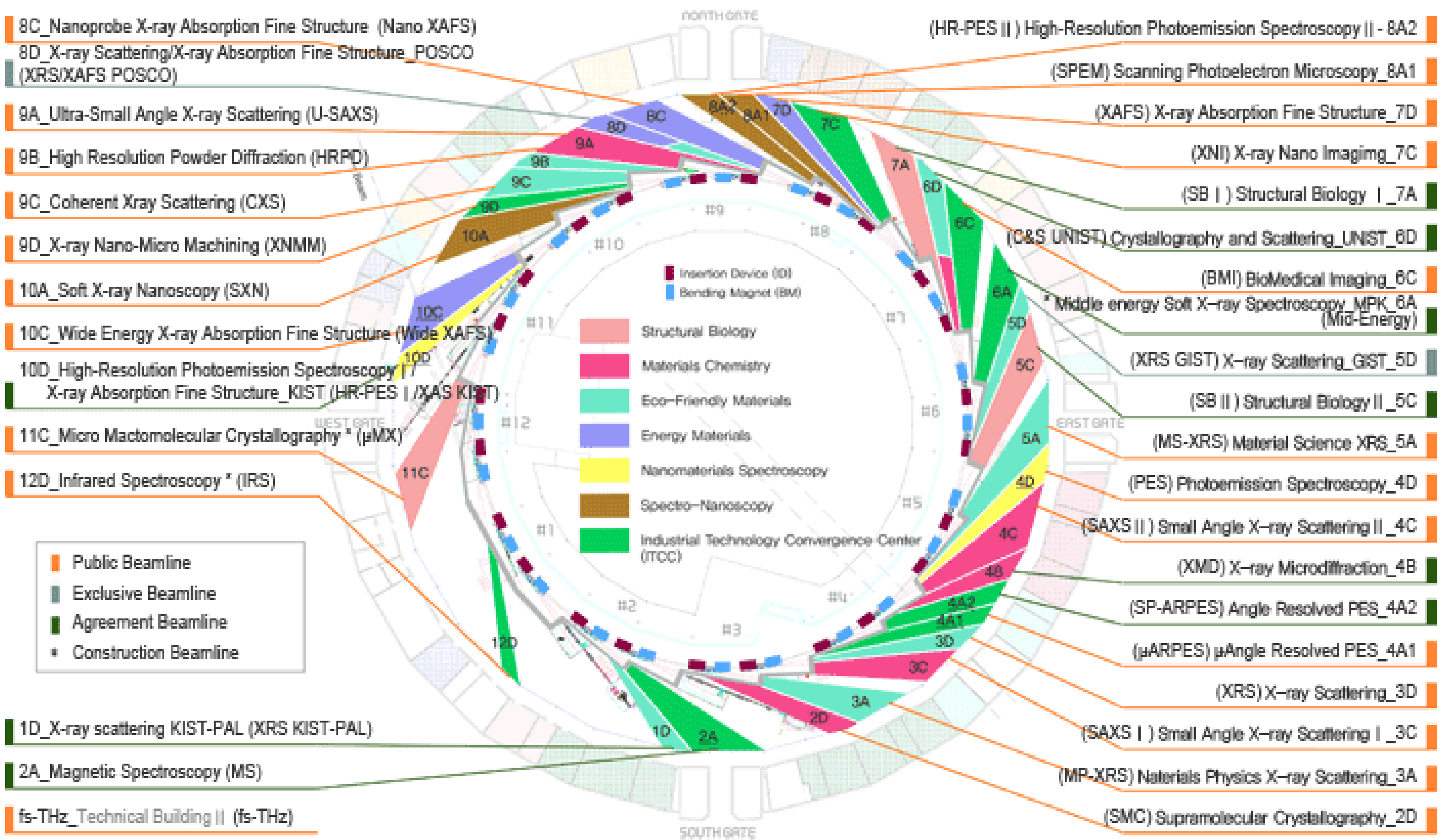
Table 1: Main Specifications of the PLS-II

Parameter	PLS	PLS-II
Beam Energy [GeV]	2.5	3.0
Beam Emittance [nm•rad]	18.9	~5 – 10
Stored Beam Current [mA]	200	400
Total Number of IDs	10	>20
Lattice	TBA	DBA
Operation Mode	Decay	Top-up
Brightness	$\sim 2 \times 10^{18}$	$\sim 10^{20}$

Table 2: Performance Goal of the PLS-II Linac

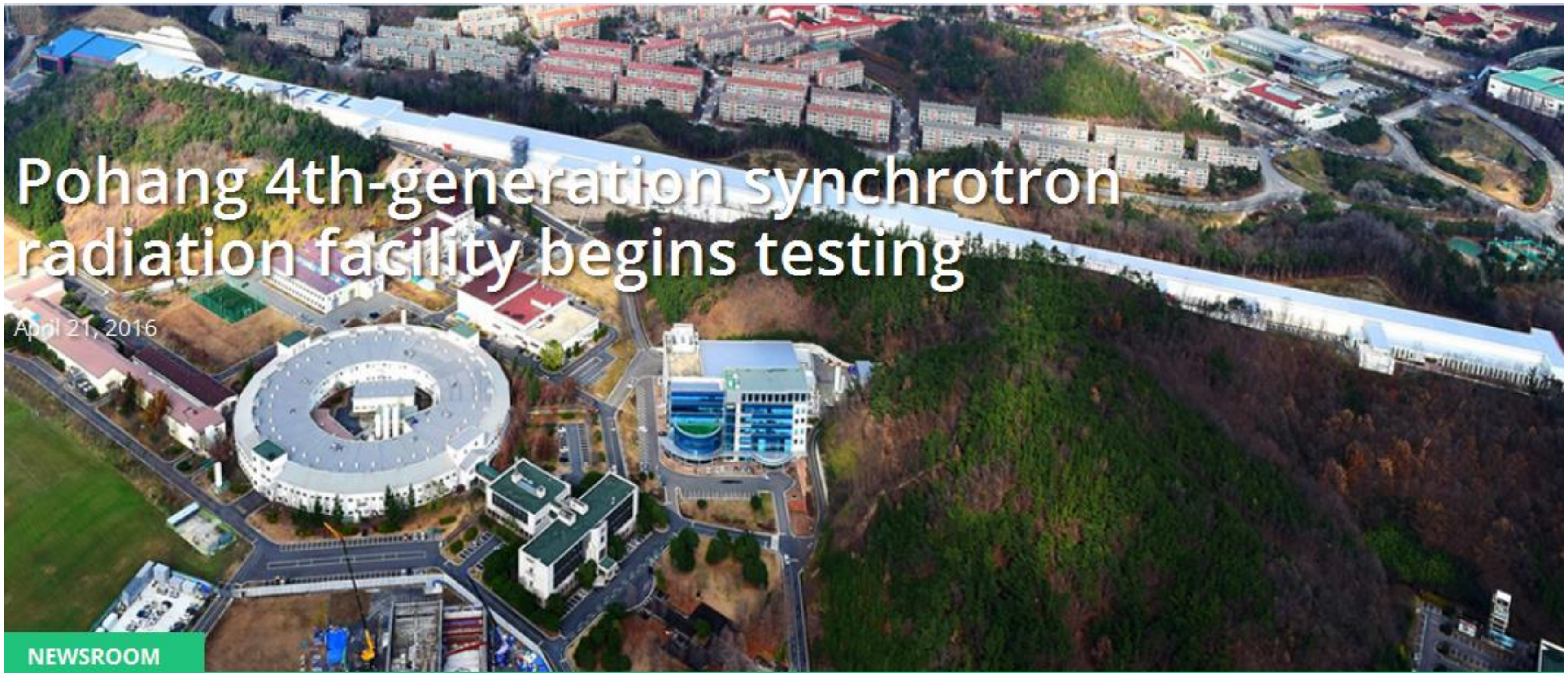
	PLS	PLS-II
Energy	2.5 GeV	3 GeV
Repetition Rate	10 Hz	10 - 30 Hz
Energy Stability	0.5% rms	0.1% rms
Energy Spread	0.6% rms	< 0.2% rms
Emittance (normalized, rms)	150 mm mrad	< 20 mm mrad
Gun Pulse Length	1.5 ns FWHM	< 1 ns FWHM
Klystron Power (Operating Levels)	50 – 60 MW	70 – 80 MW
SLED Gain	1.5 – 1.6	1.6 – 1.7
Diagnostics	BCMs, BASs, BPRMs	+ BPMs, Slits, Wire Scanners

PAL-PLS

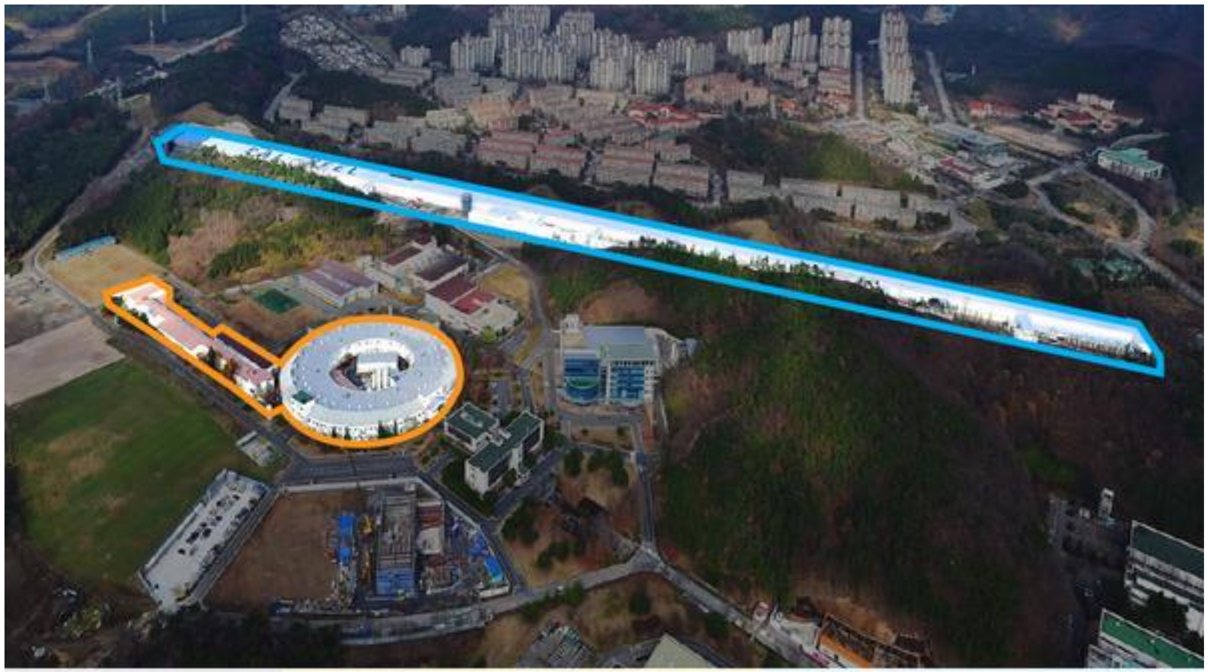


8C_Nanoprobe X-ray Absorption Fine Structure (Nano XAFS)
8D_X-ray Scattering/X-ray Absorption Fine Structure_POSCO (XRS/XAFS POSCO)
9A_Ultra-Small Angle X-ray Scattering (U-SAXS)
9B_High Resolution Powder Diffraction (HRPD)
9C_Coherent Xray Scattering (CXS)
9D_X-ray Nano-Micro Machining (XNMM)
10A_Soft X-ray Nanoscopy (SXN)
10C_Wide Energy X-ray Absorption Fine Structure (Wide XAFS)
10D_High-Resolution Photoemission Spectroscopy Ⅰ / X-ray Absorption Fine Structure_KIST (HR-PES Ⅰ /XAS KIST)
11C_Micro Mactomolecular Crystallography * (μMX)
12D_Infrared Spectroscopy * (IRS)
Public Beamline
Exclusive Beamline
Agreement Beamline
* Construction Beamline
1D_X-ray scattering KIST-PAL (XRS KIST-PAL)
2A_Magnetic Spectroscopy (MS)
fs-THz_Technical Building ǁ (fs-THz)
(HR-PES ǁ) High-Resolution Photoemission Spectroscopy ǁ - 8A2
(SPEM) Scanning Photoelectron Microscopy_8A1
(XAFS) X-ray Absorption Fine Structure_7D
(XNI) X-ray Nano Imagimg_7C
(SB Ⅰ) Structural Biology Ⅰ _7A
(C&S UNIST) Crystallography and Scattering_UNIST_6D
(BMI) BioMedical Imaging_6C
* Middle energy Soft X-ray Spectroscopy_MPK_6A (Mid-Energy)
(XRS GIST) X-ray Scattering_GIST_5D
(SB ǁ) Structural Biology ǁ _5C
(MS-XRS) Material Science XRS_5A
(PES) Photoemission Spectroscopy_4D
(SAXS ǁ) Small Angle X-ray Scattering ǁ _4C
(XMD) X-ray Microdiffraction_4B
(SP-ARPES) Angle Resolved PES_4A2
(μARPES) μAngle Resolved PES_4A1
(XRS) X-ray Scattering_3D
(SAXS Ⅰ) Small Angle X-ray Scattering Ⅰ _3C
(MP-XRS) Naterials Physics X-ray Scattering_3A
(SMC) Supramolecular Crystallography_2D
NORTH GATE
SOUTH GATE
WEST GATE
EAST GATE
Insertion Device (ID)
Bending Magnet (BM)
Structural Biology
Materials Chemistry
Eco-Friendly Materials
Energy Materials
Nanomaterials Spectroscopy
Spectro-Nanoscopy
Industrial Technology Convergence Center (ITCC)

PAL-X-FEL

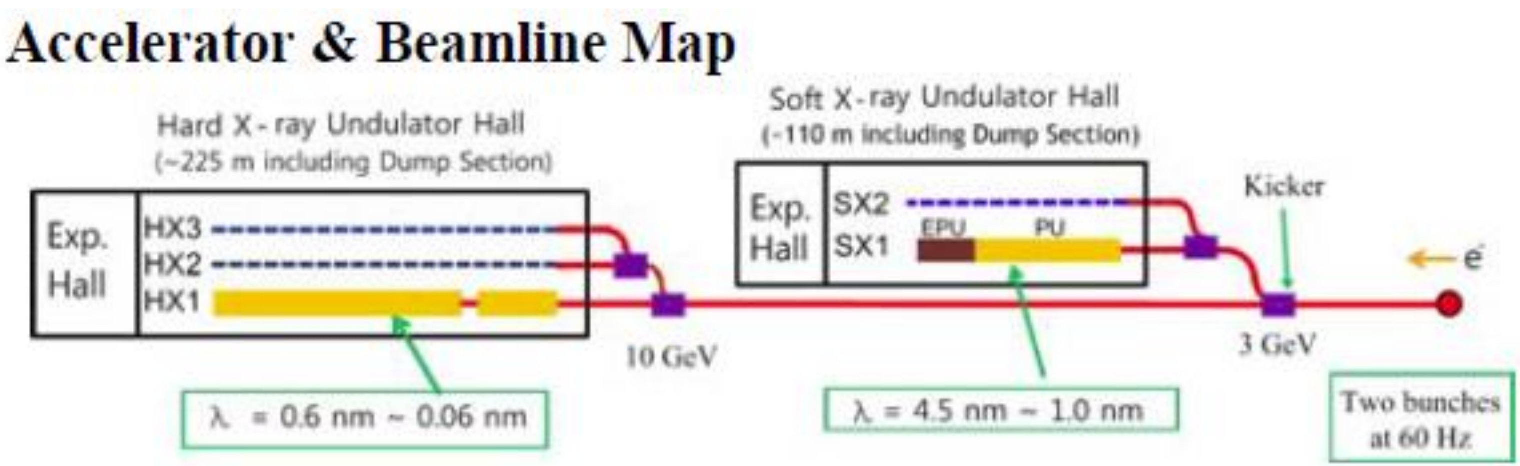

PAL-XFEL
Pohang 4th-generation synchrotron radiation facility begins testing
April 21, 2016
NEWSROOM

PAL-X-FEL



Category	Third-generation	Fourth-generation
Type of Light Source	Circular	Linear
Beam energy	2.5GeV	10GeV

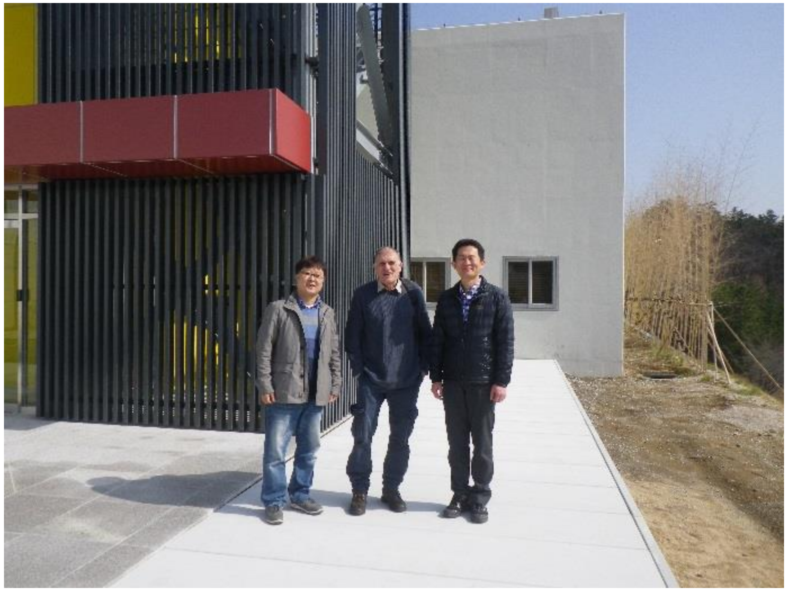
PAL-X-FEL


Accelerator & Beamline Map
Hard X-ray Undulator Hall
(~225 m including Dump Section)
Soft X-ray Undulator Hall
(~110 m including Dump Section)
Exp. Hall
HX3
HX2
HX1
Exp. Hall
SX2
SX1
EPU
PU
Kicker
e⁻
10 GeV
3 GeV
λ = 0.6 nm ~ 0.06 nm
λ = 4.5 nm ~ 1.0 nm
Two bunches at 60 Hz

PAL-X-FEL

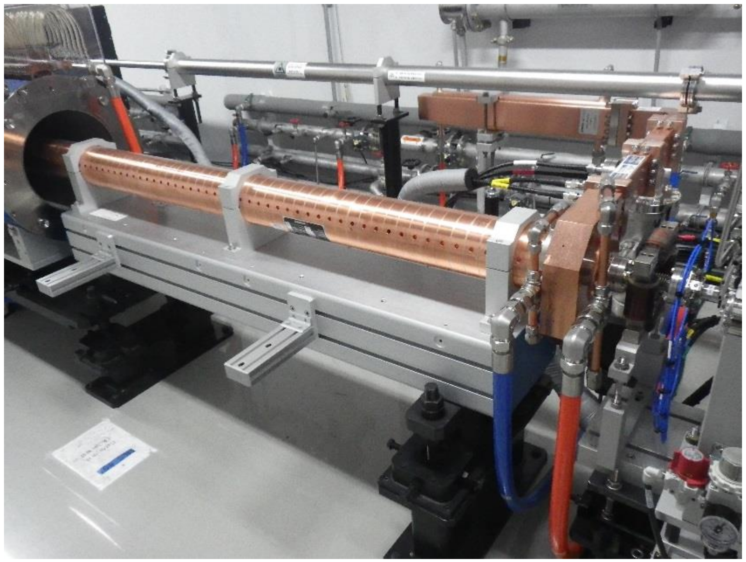
Overall length	1100 m (linac: 750m, undulator hall: 250m, beamline: 100 m)
Beam charge / slice emittance	0.2 nC / 0.4 mm-mrad
Peak current / repetition rate	3 kA / 60 Hz
Electron gun	PC RF-gun
Bunch compression	3 chicane-type BCs at 0.33 GeV, 2.52 GeV, and 3.45 GeV
No. of S-band structures	174
No. of quadrupole magnets	204
Undulator type	Out-vacuum, variable gap (min. 8.3 mm)
Wavelength range : HX1 SX1	0.6 ~ 0.06 nm (linear pol.) 4.5 ~1 nm (variable pol.)
Photon pulse length	10 ~ 180 fs
Photon flux @ 0.1 nm	> 1.0 E+12

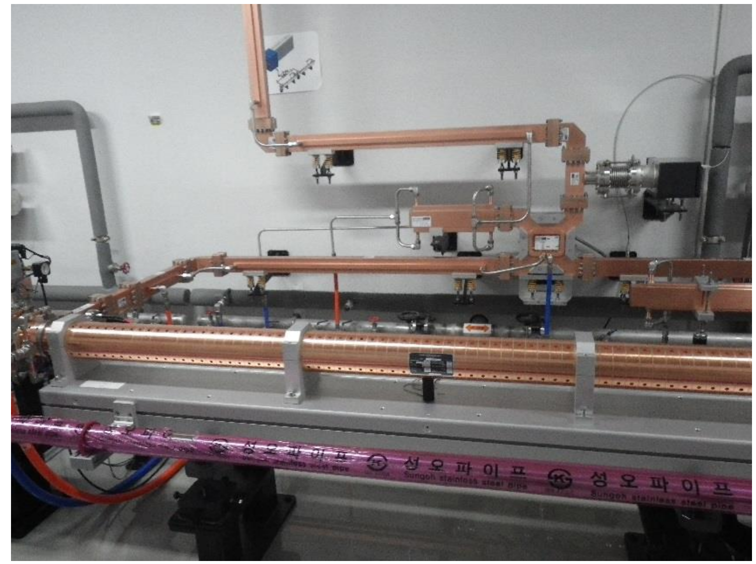
PAL-X-FEL



Left – prof. M.Chung, right – head of X-FEL diagnostics ???

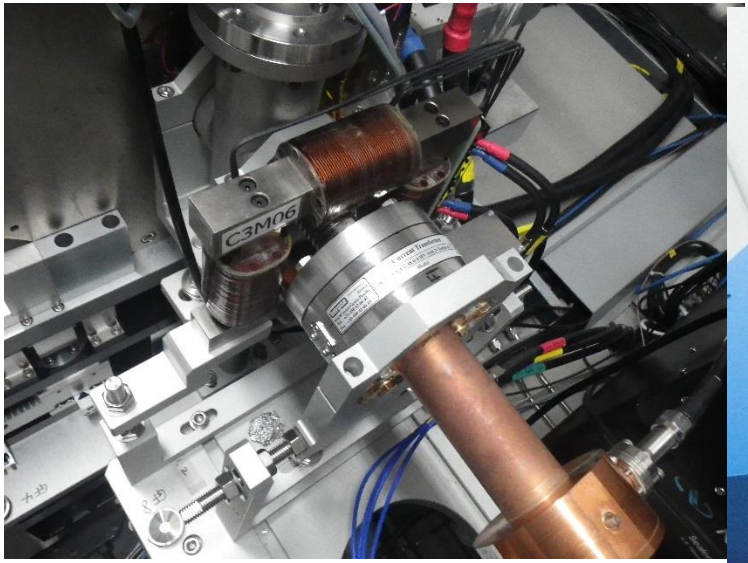
PAL-X-FEL



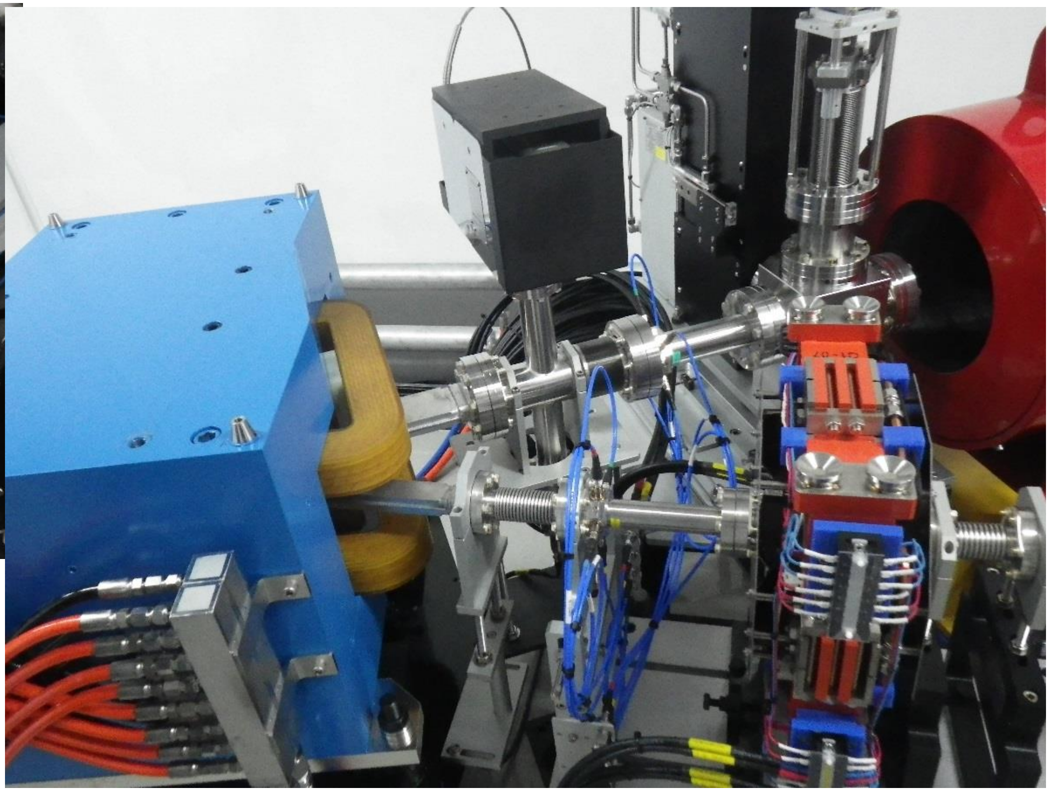


Acceleration section **RF power efficiency doubling (?)**

PAL-X-FEL

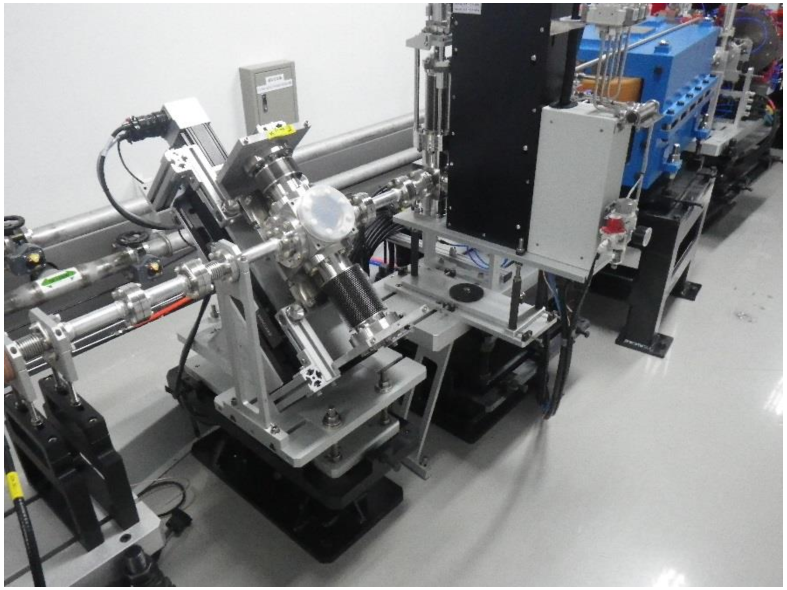


Bergoz beam current monitor

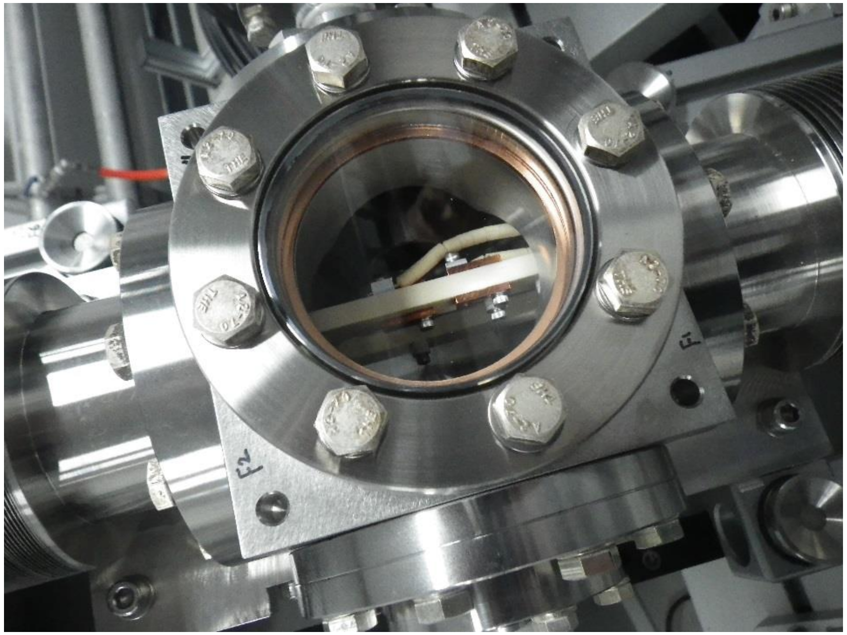


3 GeV outlet

PAL-X-FEL



Wire scanner



PAL-X-FEL

Main view

Ulsan - UNIST

Ulsan National Institute of Science and Technology (UNIST)

Goal:
To be ranked within the Top 10 Science and Technology Universities by 2030

Ulsan - UNIST

1992: “The City of Ulsan Needs a National University” ,
“Ulsan City, Setting up University Establishment Planning Team”
2001: Establishment of ‘Ulsan Citizen Organization of National University’
2002-2003: Petition for Building a National University in Ulsan
2004: Petition, Delivered to the Congress
2005: City of Ulsan announced the promotion of building a national university
2006: Selection of University Site
2007: President Moo Je Cho was appointed as the first president of UNIST and the registration of the establishment of the University was also finished

Intense Beam and Accelerator Laboratory,
Established in 2014,
Head of Lab Prof. Moses Chung

Ulsan - UNIST

Members
Faculty
391
Undergraduates
4,052
Graduates
1,332

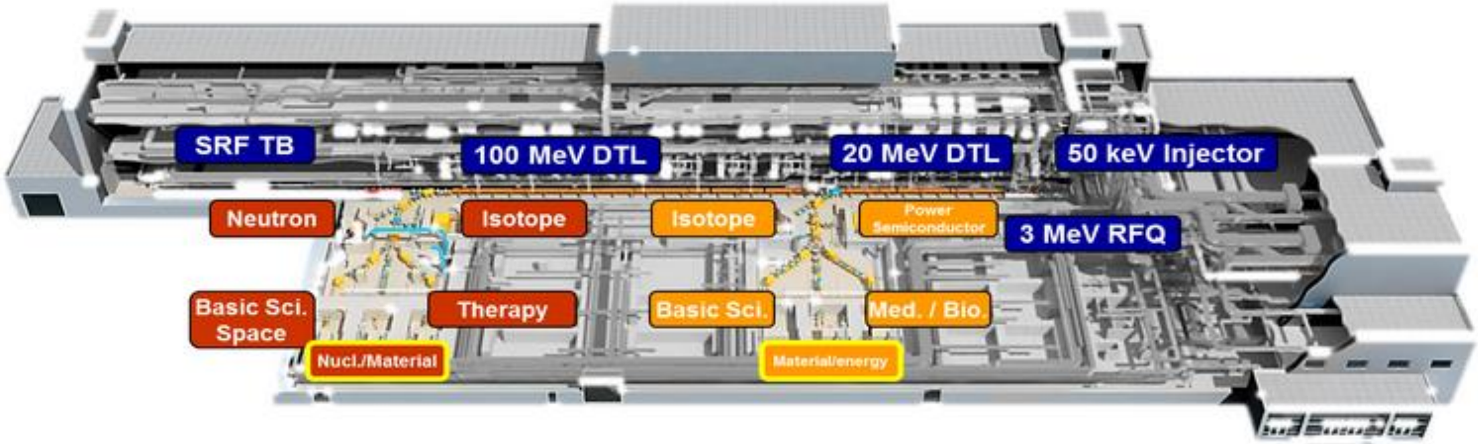
Korea Multi-purpose Accelerator Complex(KOMAC)

Vision

Branch of Korea Atomic Energy Research Institute (KAERI)
was established by ‘Proton Engineering Frontier Project
since 2002 , cost: KRW 314.3 billion (about 300 M$)

100 MeV, 20 mA, high power proton accelerator

Korea Multi-purpose Accelerator Complex(KOMAC)



Features of the 100MeV lince

- 50 keV Injector (Ion source + Low Energy Beam Transport)
- 3 MeV RFQ (4-vane type)
- 20 & 100 MeV drift tube linac (DTL)
- RF Frequency : 350 MHz
- 5 beamlines for 20 MeV & 100 MeV respectively

Include a 3 MeV, 350 MHz cw RFQ (Radio-Frequency Quadrupole) linac

Korea Multi-purpose Accelerator Complex(KOMAC)

Goal:

Output Energy (MeV)	20	100
Peak Beam Current (mA)	0.1 ~ 20	0.1 ~ 20
Max. Beam Duty (%)	24	8
Max. Average Beam Current (mA)	4.8	1.6
Pulse Widtth (ms)	0.02 ~ 2	0.05 ~ 1.33
Max. Repetition Rate (Hz)	120	60
Max. Beam Power (kW)	96	160
Emitencee (mm - mrad)	0.22(x), 0.25(y)	0.3(x), 0.3(y)

Korea Multi-purpose Accelerator Complex(KOMAC)

Goal: 20 MeV proton Beamline

Target Room	Application Field	Repetition Rate	Max. Average Beam Current	Irradiation Condition
TR21	Semiconductor, Nano Science	60Hz	0.6 mA	Horizontal / Air
TR22	Life & Medical Science	15Hz	60 mA	Horizontal(Vertical) / Air
TR23	Material, Energy, Environment, Nano Science	30Hz	0.6 mA	Horizontal / Air
TR24	Basic Science, Nuclear Physics	15Hz	60 mA	Horizontal / Air & Vacuum
TR25	Isotope	60Hz	1.2 mA	Horizontal / Vacuum

Korea Multi-purpose Accelerator Complex(KOMAC)

Goal: 100 MeV proton Beamline

Target Room	Application Field	Repetition Rate	Max. Average Beam Current	Irradiation Condition
TR101	Isotope	60Hz	0.6 mA	Horizontal / Vacuum
TR102	Medical Science(Proton Therapy)	7.5Hz	10 μA	Horizontal / Air
TR103	Nuclear & Material Science	15Hz	300 μA	Horizontal / Air
TR104	Basic Science, Nuclear Physics, Space radiation	7.5Hz	10 μA	Horizontal / Air & Vacuum
TR105	Neutron Source	60Hz	1.6 mA	Vertical / Air + Vacuum

Ionisation loses

Ionization losses - Bethe-Bloch formula

$$-\frac{dE}{dx} = 2\pi N_a r_e^2 m_e c^2 \rho \frac{Z}{A} \frac{z^2}{\beta^2} \left[ln\left(\frac{2m_e c^2 \gamma^2 \beta^2 W_{max}}{I^2}\right) - 2\beta^2 - \delta - 2\frac{C}{Z} \right]$$

E_p, MeV	dE/dx, MeV/cm
10	384.63
11	359.923
12	338.574
13	319.921
14	303.4686
15	288.837 1
16	275.7309
17	263.9158
18	253.204
19	243.44368
20	234.5089

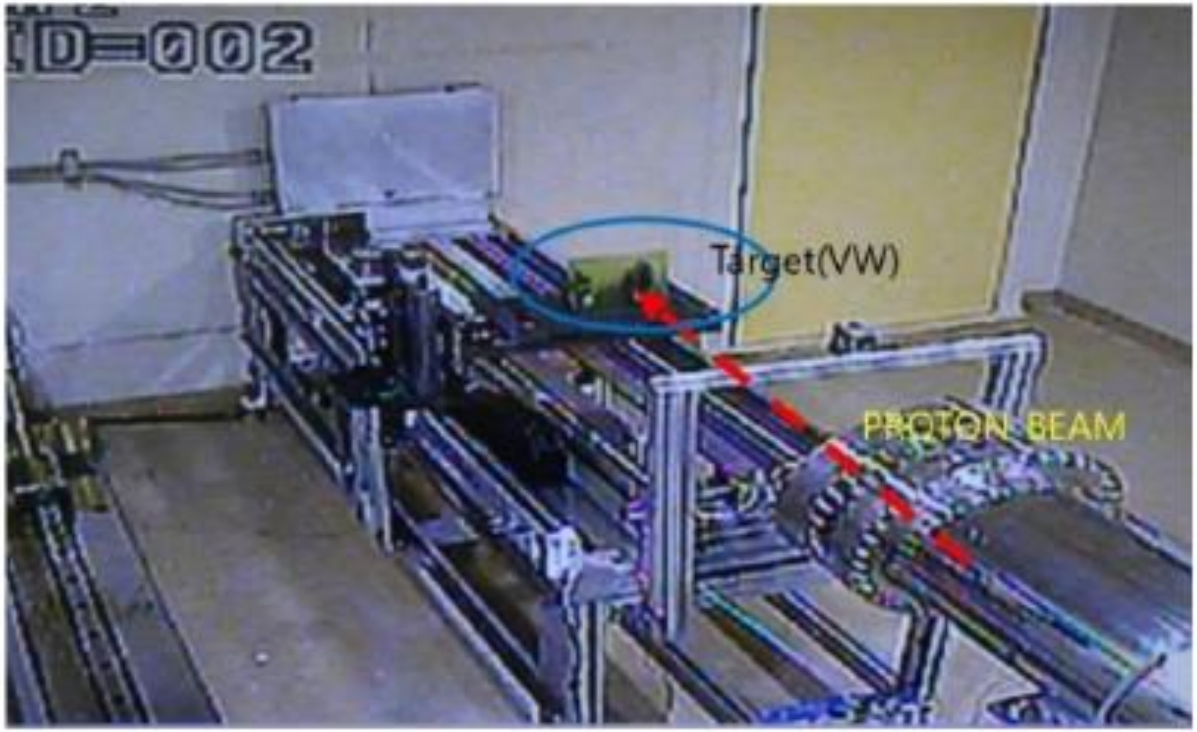
Tungsten wire with diameter 100 µm
Losses of 1 proton: 2.27 MeV
Proton beam with sigma 15 mm
Wire deposited current 2.17E-10 A
Wire deposited power 2E-4 W
Wire T increase 9E-2 K
Frequency shift 0.335Hz (depending on convection coefficient 80 W/m^2/K and transformation coefficient 0.4)

VWM Experiment Conditions at KOMAC

Energy of proton beam:
20 MeV at exit from vacuum chamber, 14.5 at VWM position (1 m from exit) in air
Repetition rate: 1 Hz, Mean current: 100 nA (at 1 Hz rep. rate)

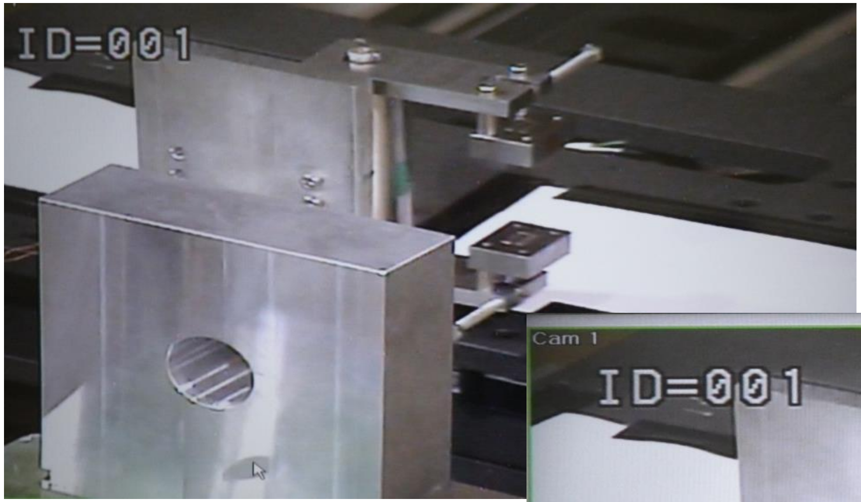
Wire length: 80 mm,
Wire type: W
VWM aperture: 40 mm

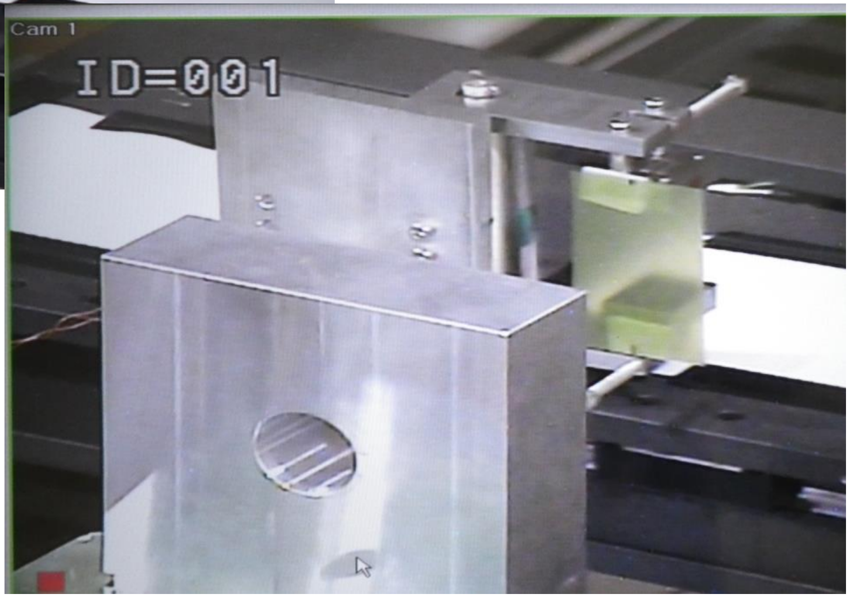
3D Table



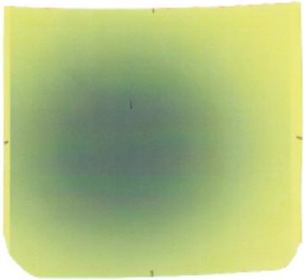
VWM installation in KOMAC

VWM mounted on the 3D table





film CAFCHROMIC Type HD-V2



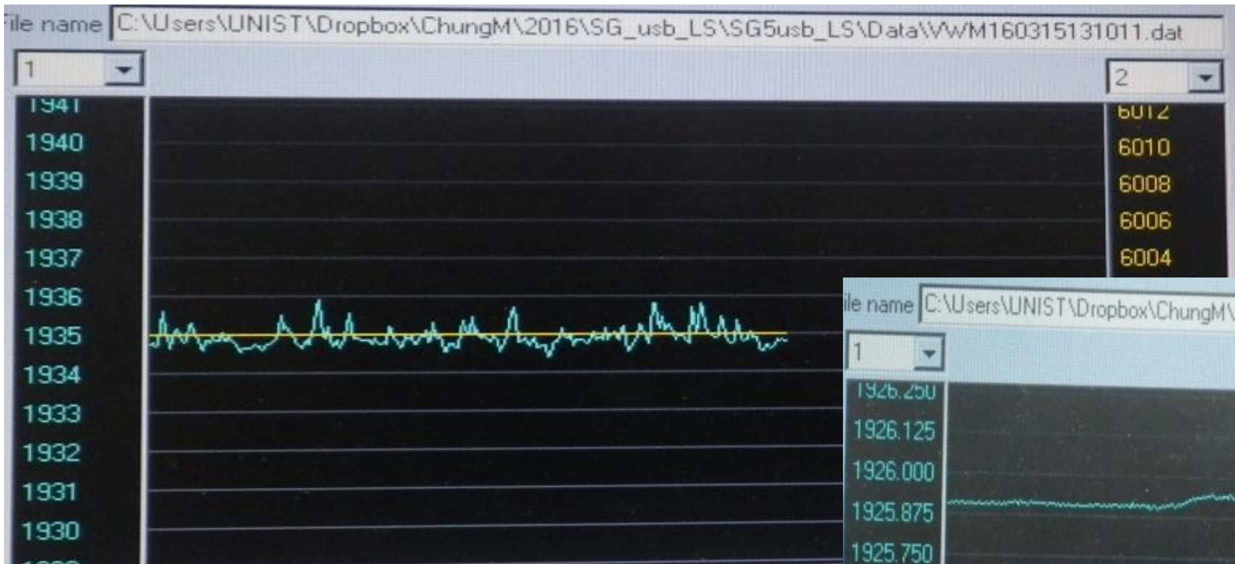
Collimator
D=30 mm

VWM covered with convection protection box

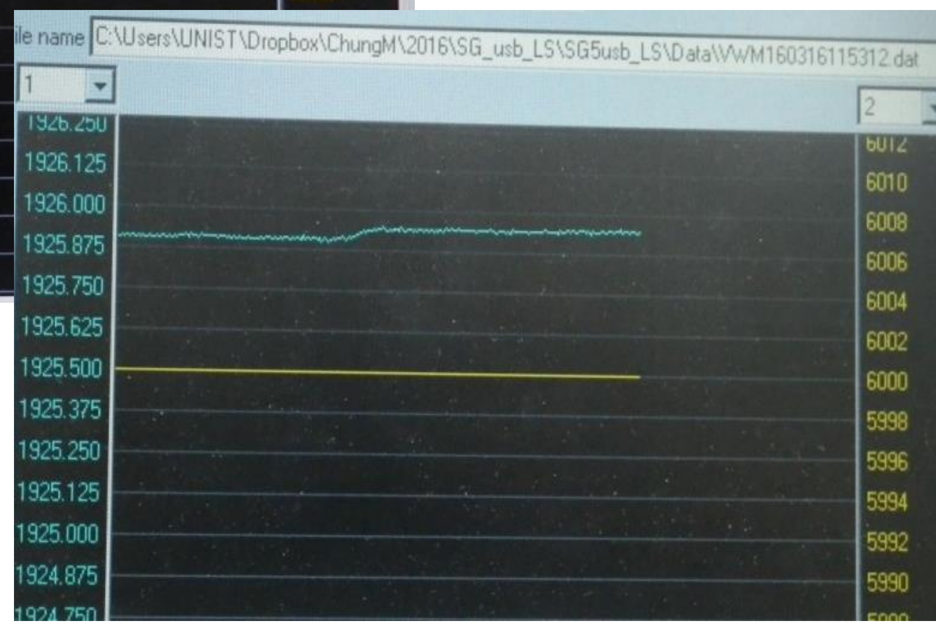
Immediately after beam start (film saturated during few train shots)

Collimator and convection protection box, covered with film CAFCHROMIC

VWM convection dependence

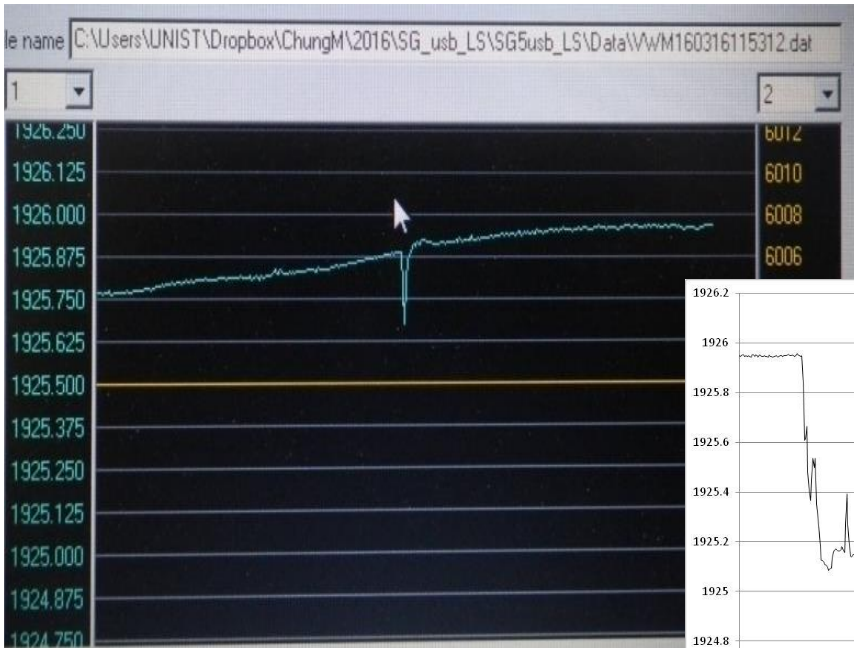


With protect box



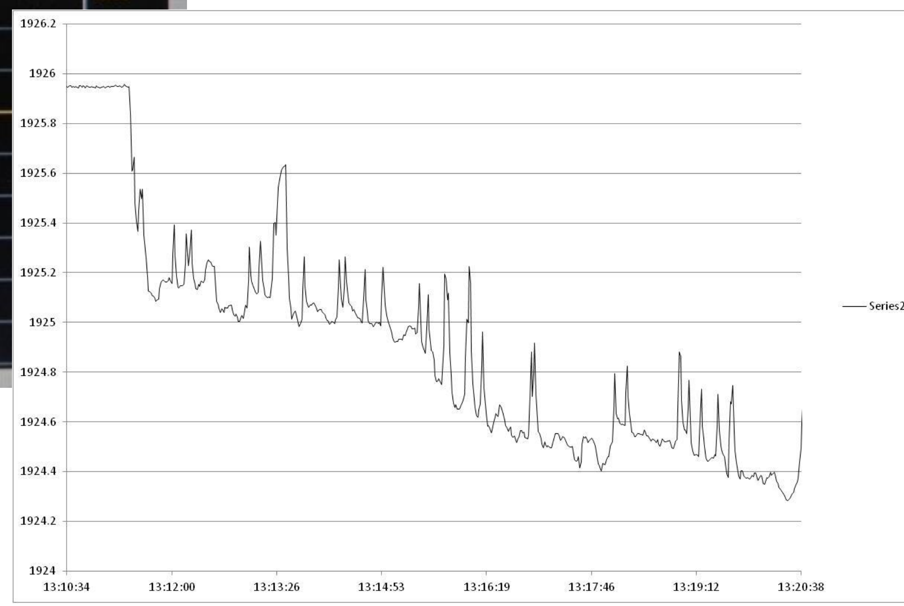
Without protect box

VWM one_shot/continuos measurements

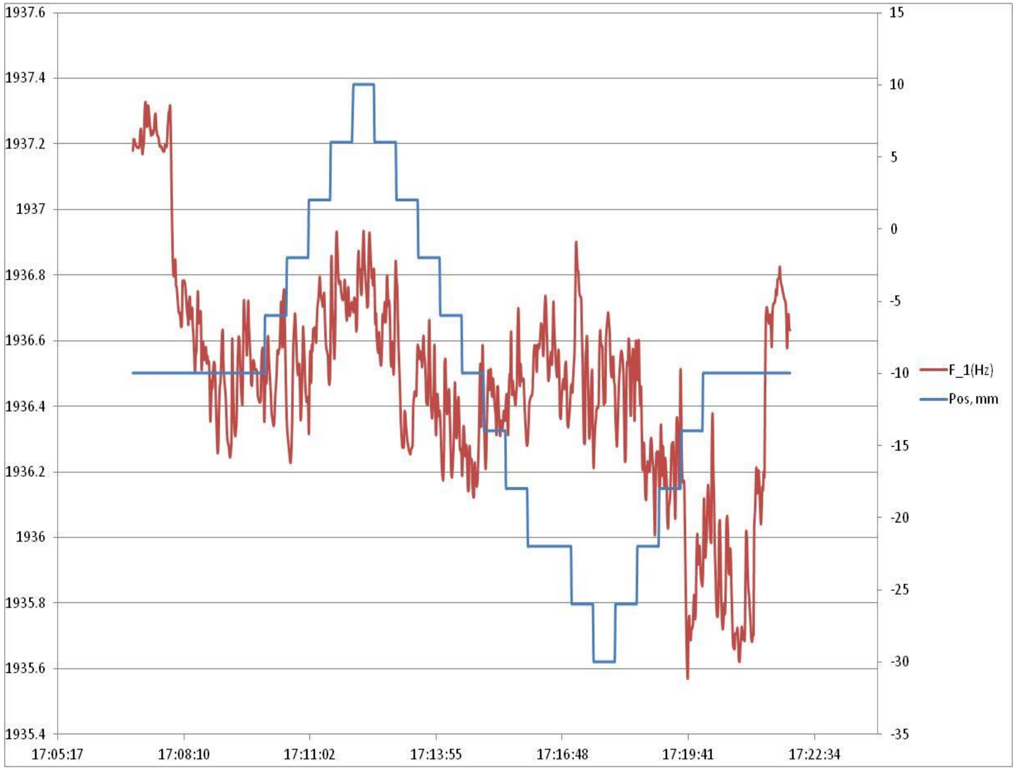


One shot of proton beam

Typical behavior of VWM signal with 1 Hz repetition rate beam

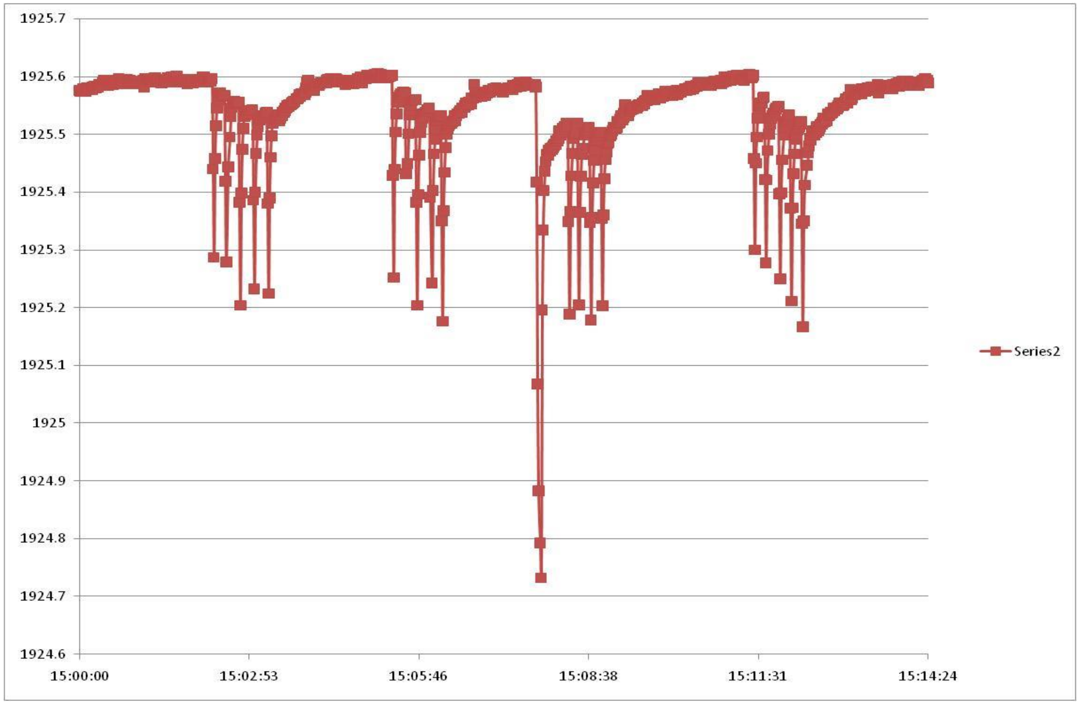


VWM scan with 1 Hz repetition



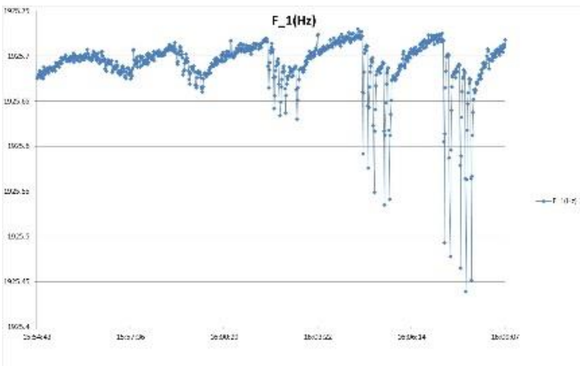
Scan on 1 Hz repetition rate proton beam

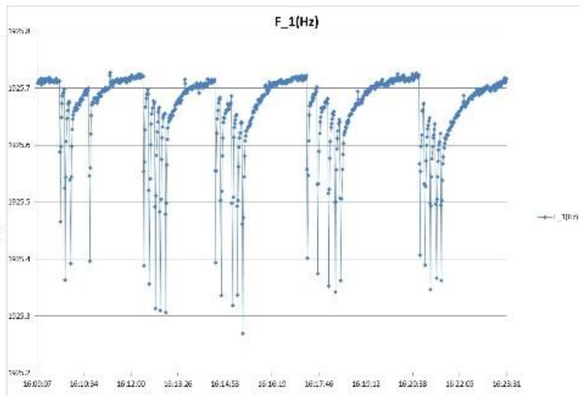
Mode: one train - 10 sec pause

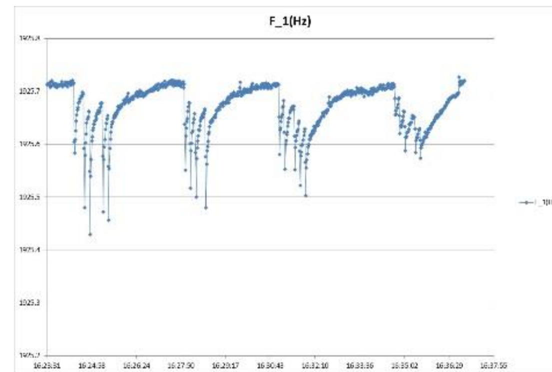


Different series of pulses. The first and fourth are more regular in time and amplitude of the peaks, in the second the second train is obviously weak, in the third we saw non regular time structure of trains.

Regular scan (typical)

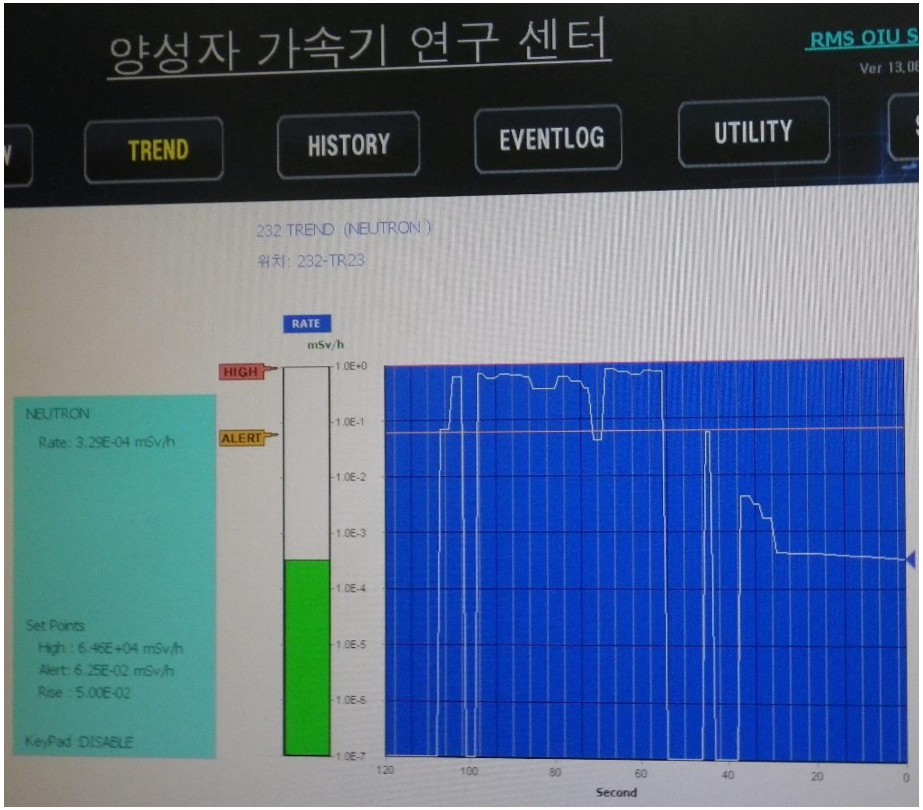






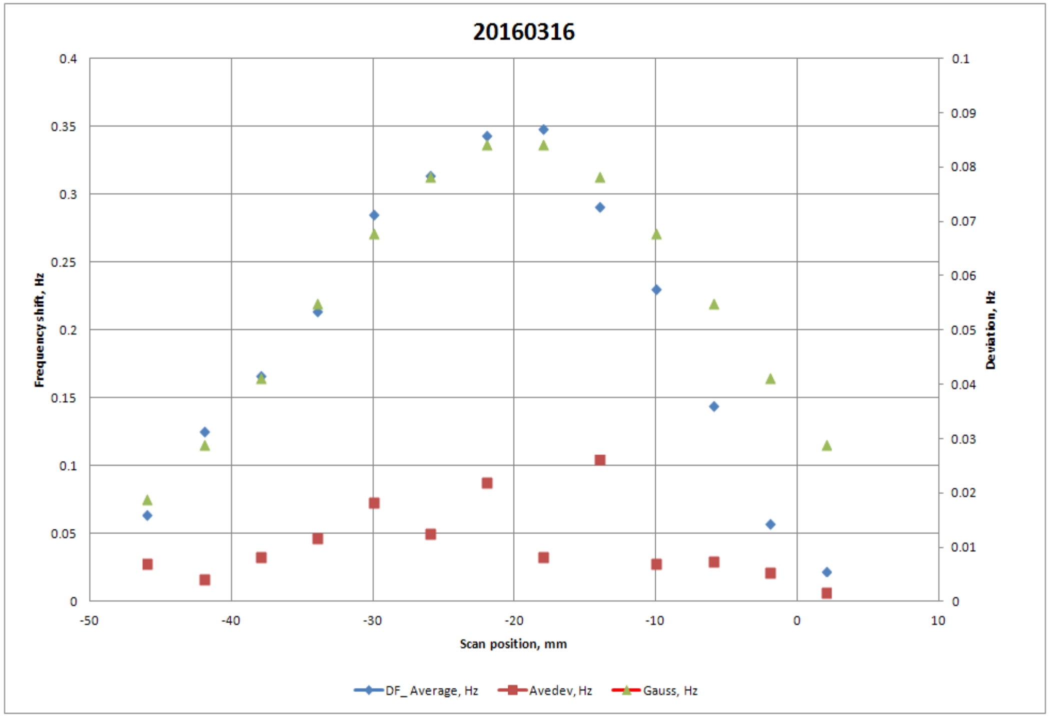
Regular scan: 4 mm step

Beam profile reconstruction



The proton beam indirectly was measured by neutron detector (type ?) mounted outside from beam path. Before VWM the proton beam was marked by this detector only. **Not all events from this detector are attended to real beam measured by VWM!!!**

Beam profile reconstruction



Blue dots - reconstruction
Green dots - Gaussian with sigma 15 mm
Red dots – deviation (right axis)

KOMAC Future

To find and suggest the proper implementation of VWM in KOMAC

design of KOMAC is nominal 20 mA in linac

Our experiment was on 100 nA (0.3 Hz response, dynamic range of VWM about few 100 Hz, i.e. possible full scan about 100 μA)

- ❑ Usage as beam position monitor - vacuum experiments are needed
- ❑ Resonant Target VWM implementation
- ❑ Beam stations instrumentation with VWM (air/vacuum, not fixed conditions) , for example
  - Medical Science(Proton Therapy) – 10 μA
  - Nuclear & Material Science – 300 μA
  - Basic Science, Nuclear Physics, Space radiation - 10 μA

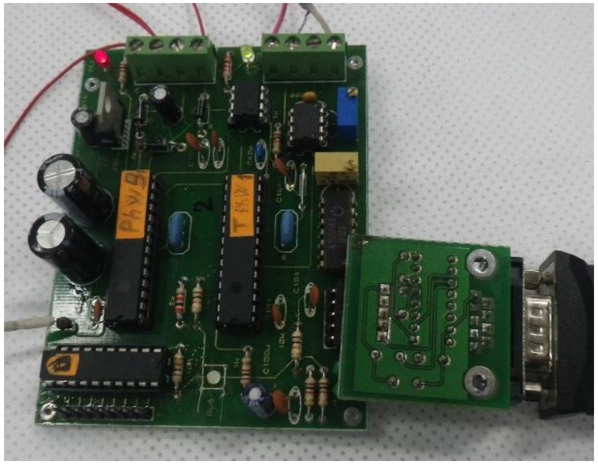
VWM Experiment Team at KOMAC

Su Jae Kim[3] Dongnyung Choe[2] S.G.Arutunian[1]
Moses Chung[2] Seong-Yeol Kim[2]

1 YerPhI, 2 UNIST, 3 KOMAC

Future

1. Resonant target VWM experiments on photon beams YerPhI/UNIST
2. Resonant target VWM experiments on KOMAC proton beam (small KOMAC/UNIST Project)
3. Gd covering on the Tungsten wire UNIST/YerPhI
4. Test experiments of neutron beam detection (neutron station)
5. Large Project on instrumentation in radiation medicine
6. ISTC neutron Project
7. Tomography Project
8. Other



RT VWM new electronics

Acknowlegments

Author is grateful to Prof. Moses Chung for collaboration

Kamsa-hamnida

감사합니다