國家同步輻射研究中心
National Synchrotron Radiation Research Center

Status of Radiation Safety System at Taiwan Photon Source

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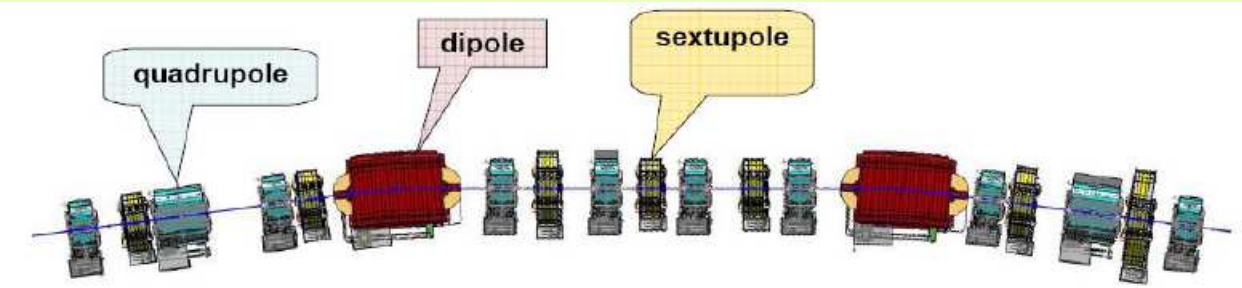
NSRRC layout

Major parameters of TPS

Energy	3 GeV
Current	500 mA at 3 GeV (Top-up injection)
SR circumference	518.4 m ($h = 864 = 2^5 \cdot 3^3$, dia.= 165.0 m)
BR circumference	496.8 m ($h = 828 = 2^2 \cdot 3^2 \cdot 23$, dia.= 158.1 m)
Lattice	24-cell DBA
Straight sections	12 m x 6 (σ_v = 12 μm, σ_h = 160 μm) 7 m x 18 (σ_v = 5 μm, σ_h = 120 μm)
Bending magnets	48
Emittance	1.6 nm·rad at 3 GeV (Distributed dispersion)
Coupling	1 %
RF frequency	500 MHz
RF gap voltage	2.8~3.5 MV (3 SRF cavities)
RF power	750 kW (3 SRF cavities)

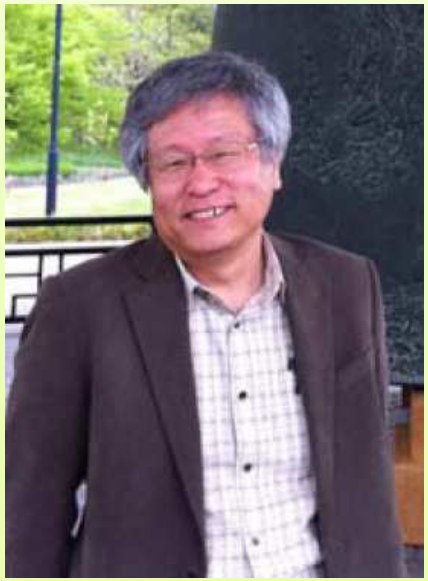


Radiation Safety System of TPS

- PAST
  - External review of preliminary Safety Analysis Report (SAR)
  - Revised SAR submitted to Taiwan AEC and approved
- NOW
  - Accelerator shielding is completed
  - Shielding design for 7 phase I beamlines is under-way
  - Performance verification of radiation detector
  - Commissioning of LINAC and SRF
- FUTURE
  - Installation of access control system
  - Deployment of detector and monitoring network
  - Radiation safety control of commissioning

TPS SAR peer review and approval

- Preliminary SAR was drafted and reviewed in 2009
- Methodology, tools and results were reviewed.
- Final SAR submitted to Taiwan Atomic Energy Council in 2010.
- Installation permission of high intensity radiological facility was granted in 2010.



Dose limit: TPS vs TLS & others

Parameter	ALS	SSRL	NSLS-II	APS	TLS	TPS
Ring Circumference (m)	197	234	792	1104	120	**518**
Stored Beam Energy (GeV)	1.9	3	3	7	1.5	**3**
Stored Current, I (mA)	400	500	500	100	400	**500**
Stored Energy (J)	500	1200	4060	2578	240	**2590**
Stored Beam Power, Ps (MW)	760	1500	1500	700	600	**1500**
Design Lifetime, τ (h)	8	10	3	54	5	**7**
Typical Straight Length (m)	6	6	6.6	15	6	**7-12**
GB Power from Straight (μW)	19	38	42	44	16	**47-80**
Ring Floor Shielding Limit (mSv y^{-1})	2	1	5	5	2	**1**
Beamline Shielding Limit (mSv y^{-1})	1	1	1	1	2	**1**
Site Boundary Dose Limit (mSv y^{-1})	0.1	0.05	0.05	0.1	0.1	**0.5**

Ref: Radiat Prot Dosimetry. 2009 Nov;137(1-2):18-34

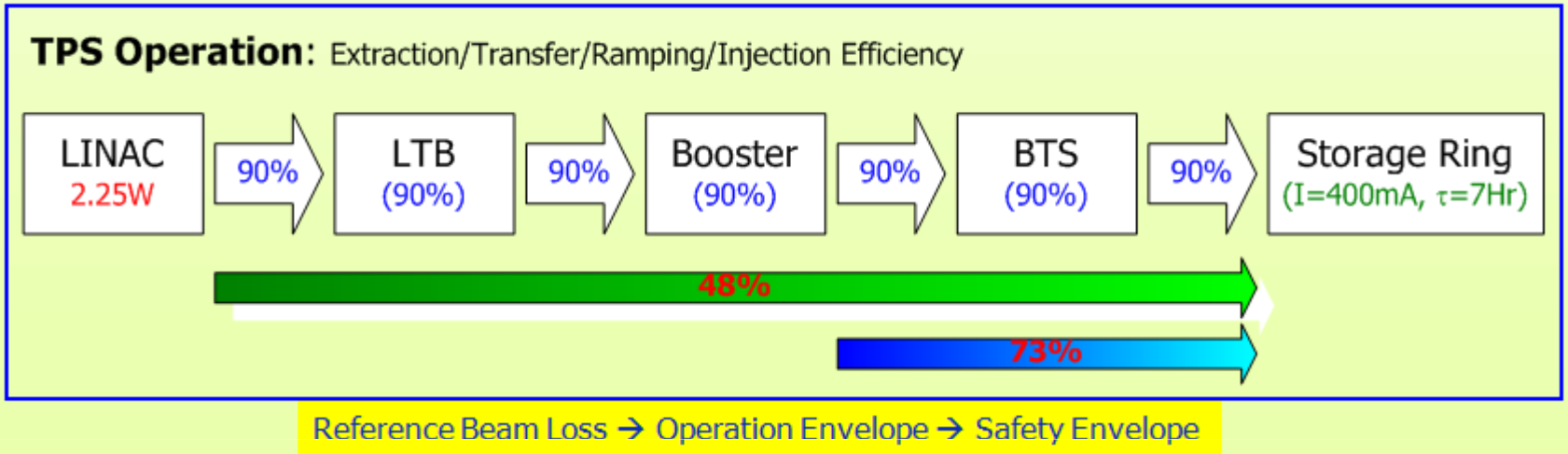
Progress of TPS construction

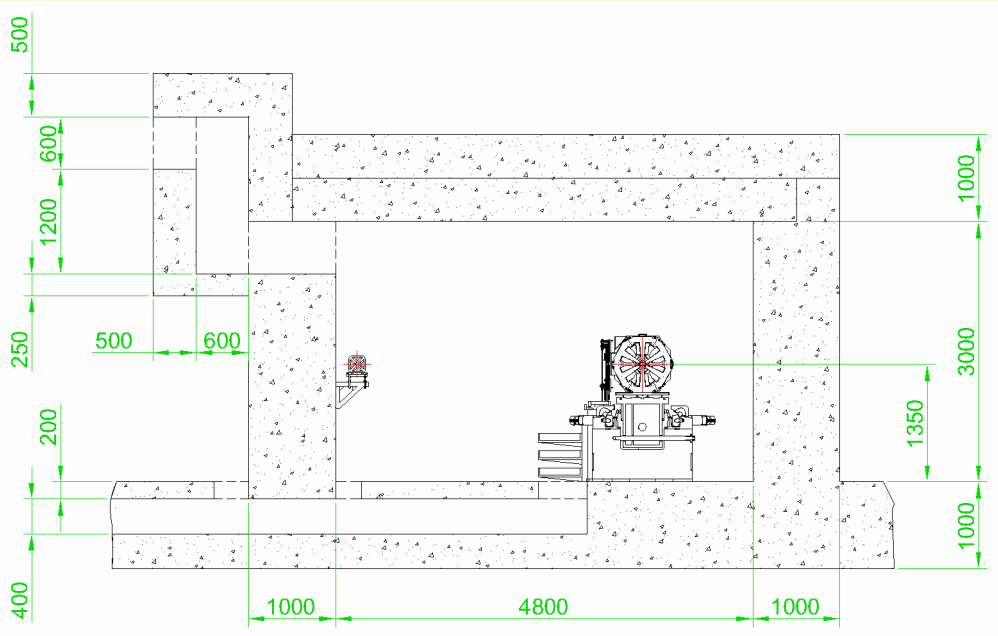
2010 TLS only

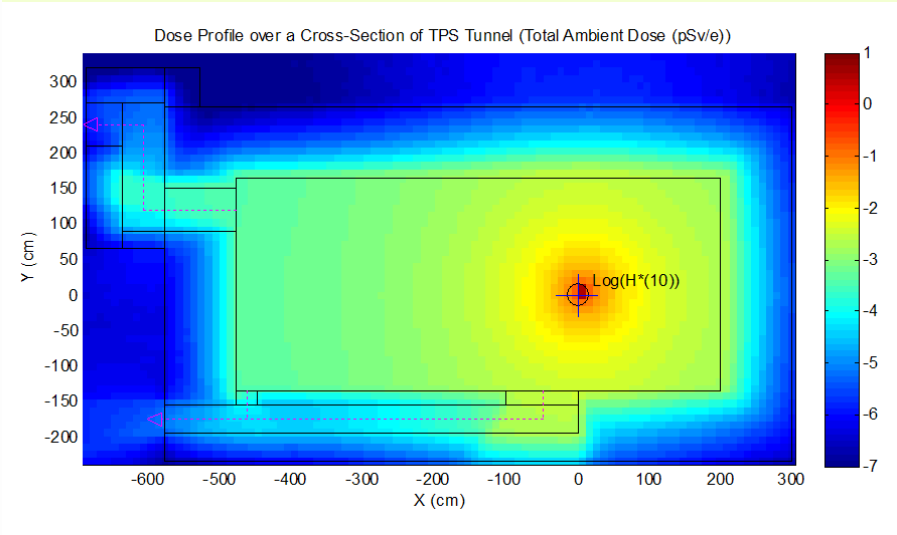
2012

2013 TLS+TPS

Shielding & dose simulation

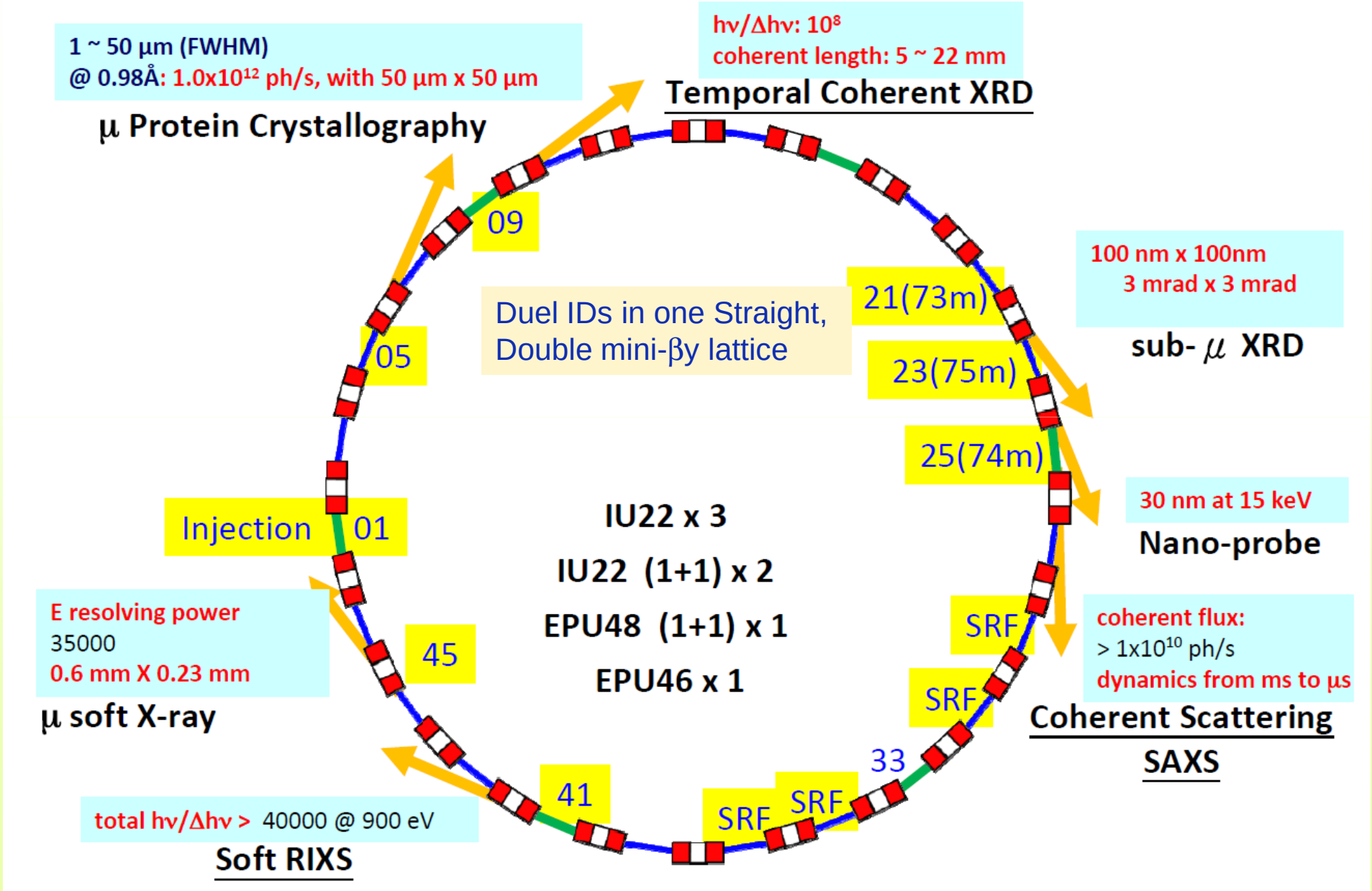






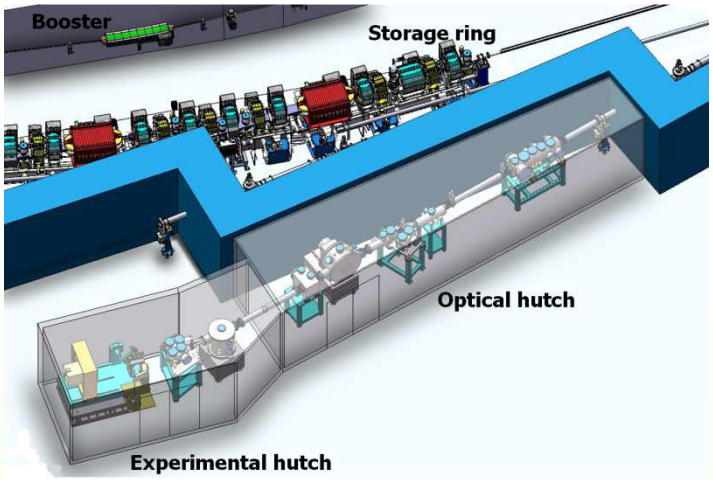
Accelerator shielding

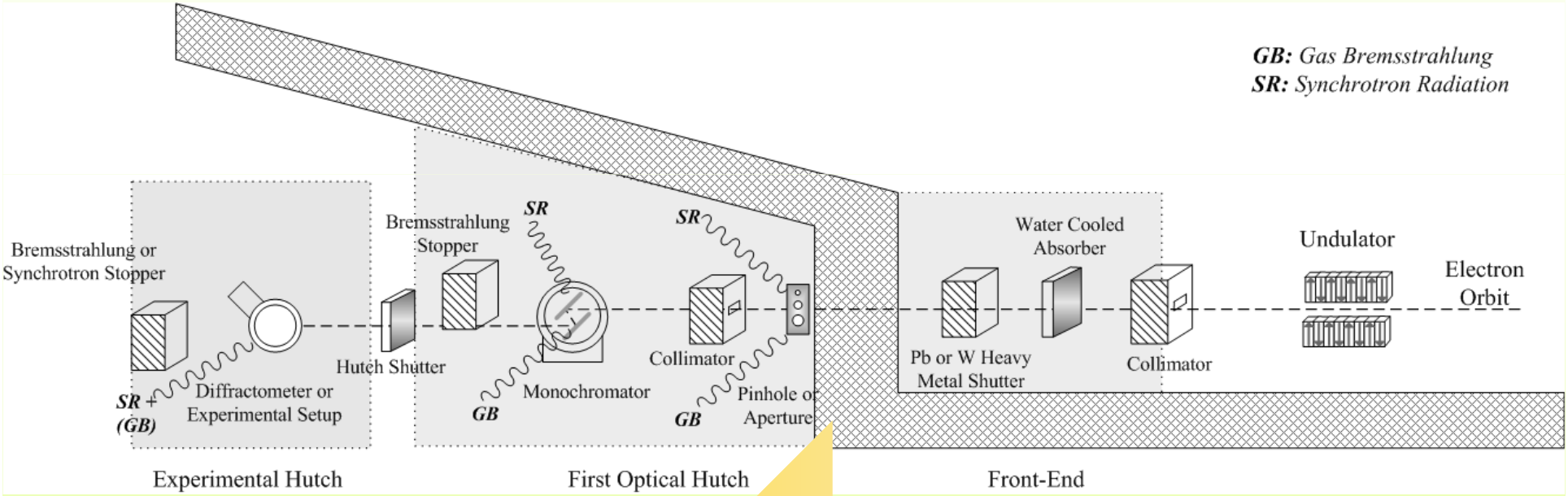
TPS Phase-I Beamline



Beamline shielding

- Bremsstrahlung: collimator, stopper, local shielding. Monte-Carlo code: FLUKA
- Synchrotron: hutch, shielding enclosure, exclusion zone. Analytical code: STAC8



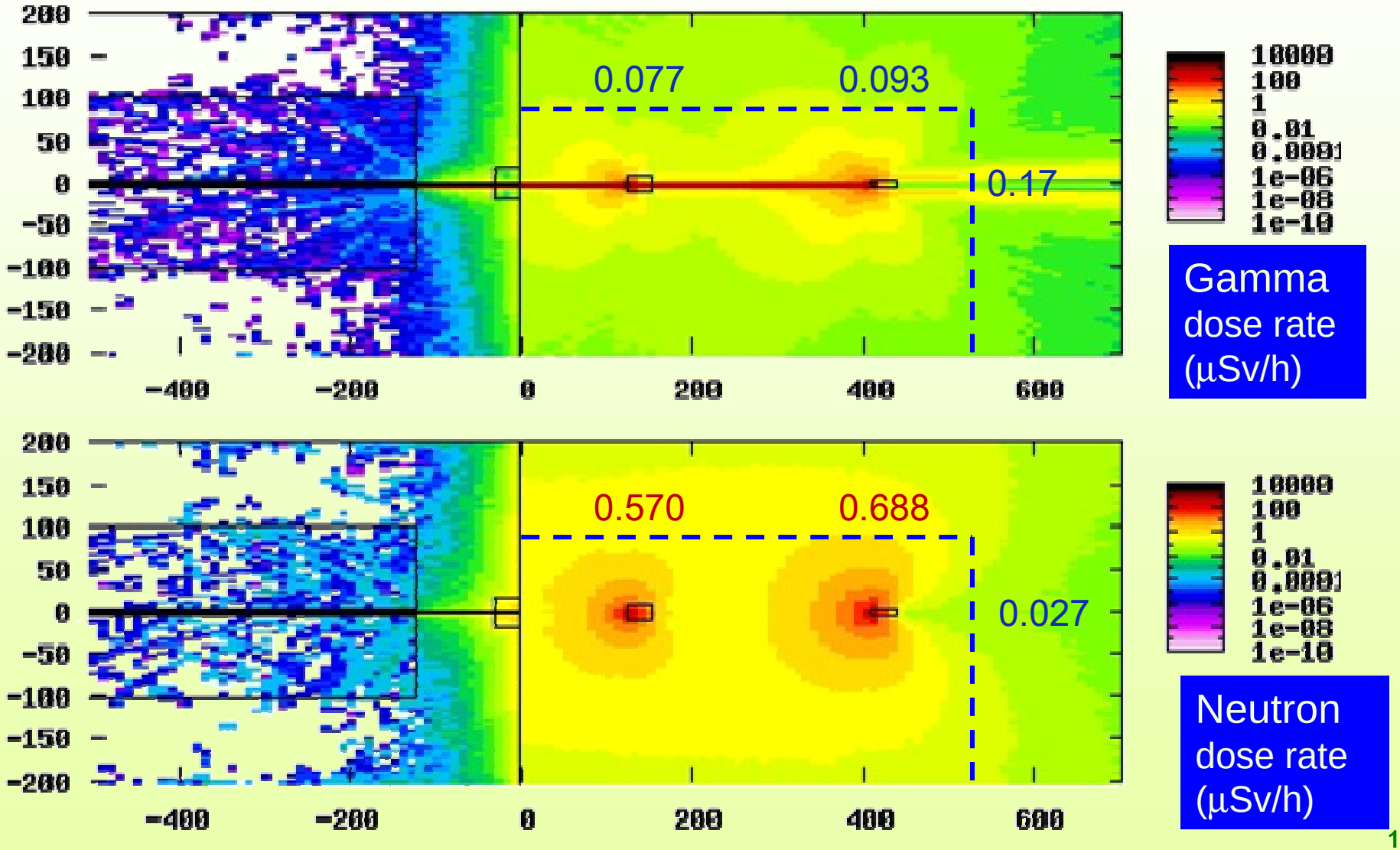


Dose rate limit: 0.5μSv/h
Where users are accessible.

Synchrotron Radiation: Low energy, high flux
Bremsstrahlung: High energy, low photon flux
1. Gas bremsstrahlung
2. Bremsstrahlung streaming from beam loss

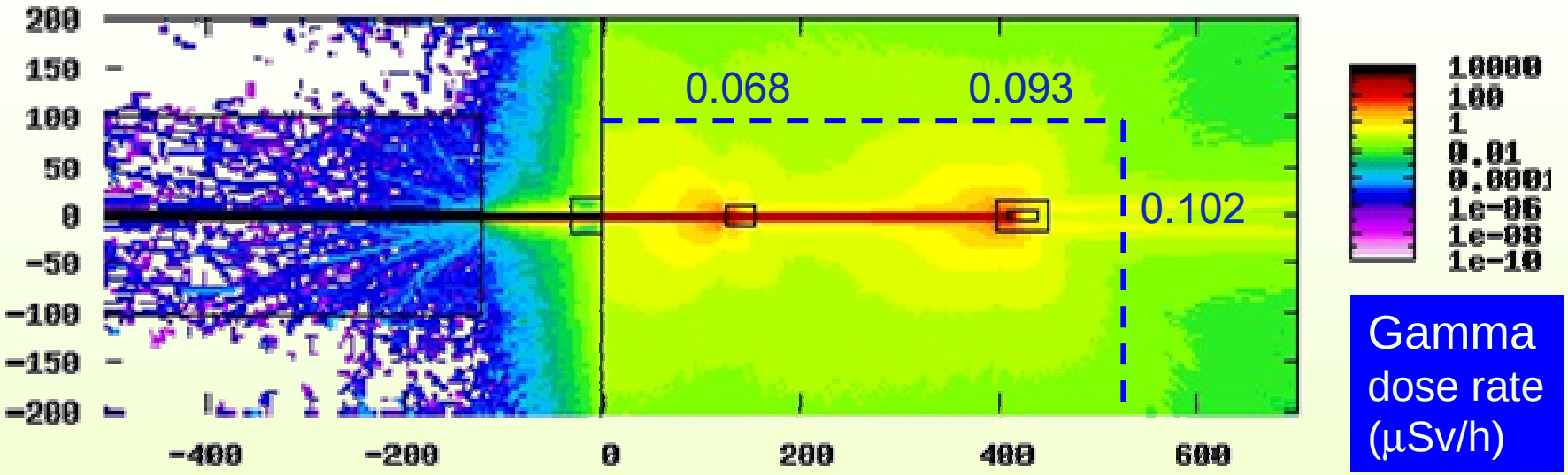
Dose assessment for GB scattering

30cm PB Collimator ⇨ 30cm W Stopper

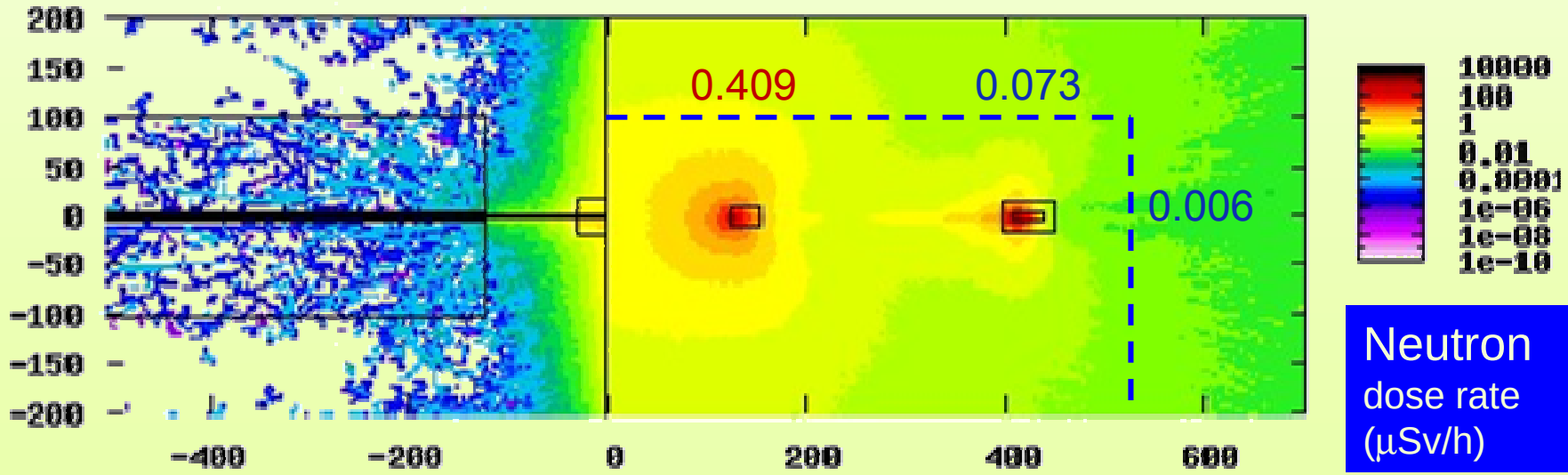


Dose assessment for GB scattering

10cm PE Enclosure around Stopper



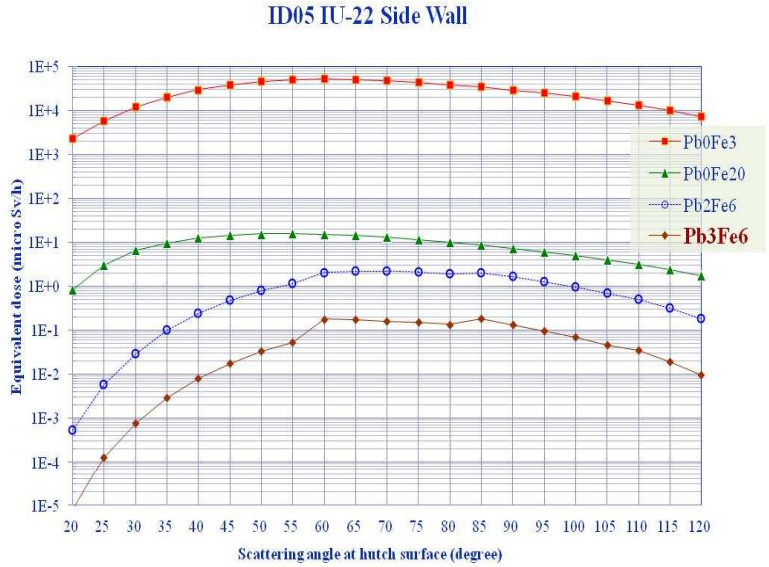
Gamma dose rate (μSv/h)

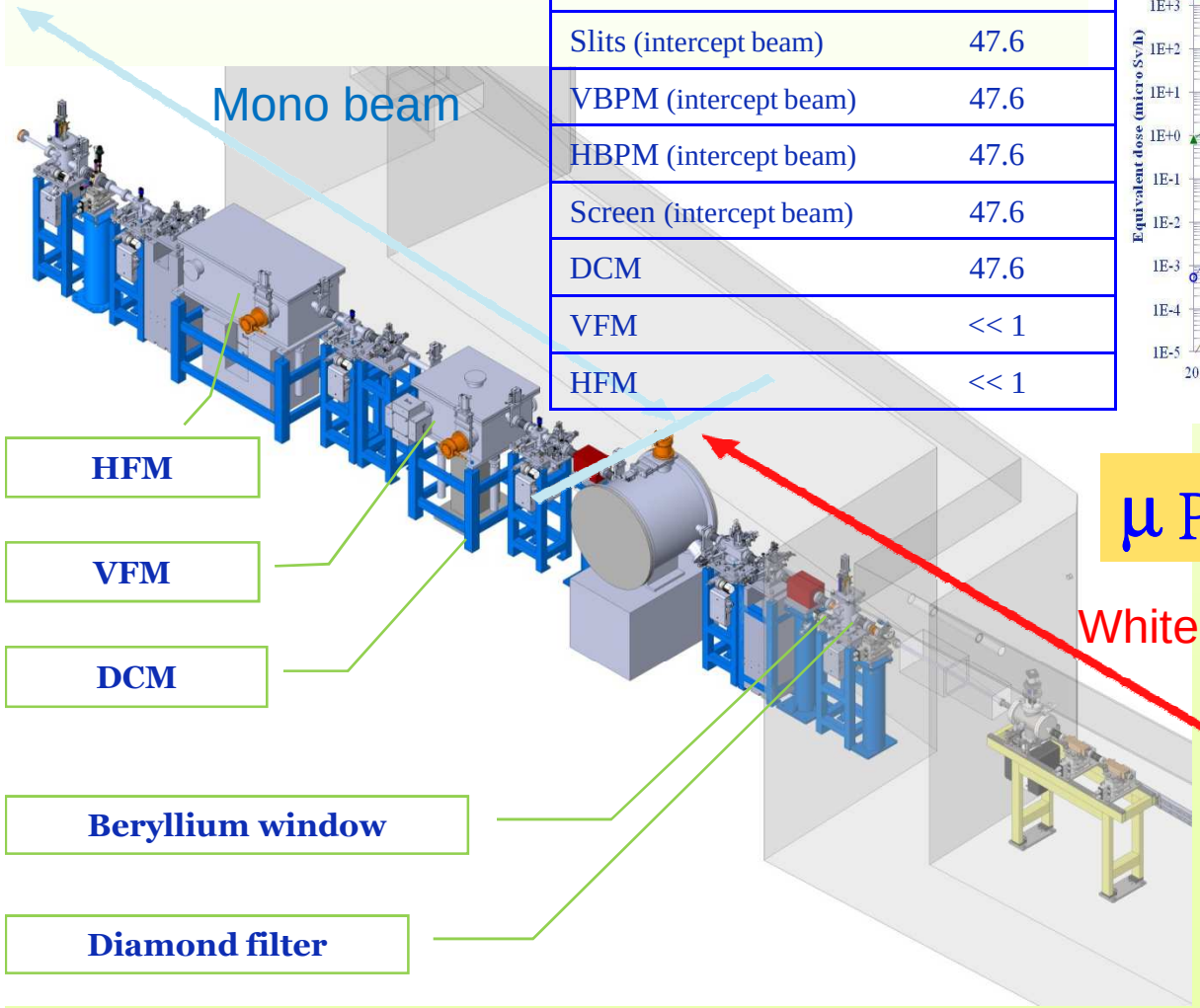


Neutron dose rate (μSv/h)

Dose evaluation for synchrotron

	Power loss, W
Diamond filter	37.7
Be window	2
Slits (intercept beam)	47.6
VBPM (intercept beam)	47.6
HBPM (intercept beam)	47.6
Screen (intercept beam)	47.6
DCM	47.6
VFM	<< 1
HFM	<< 1

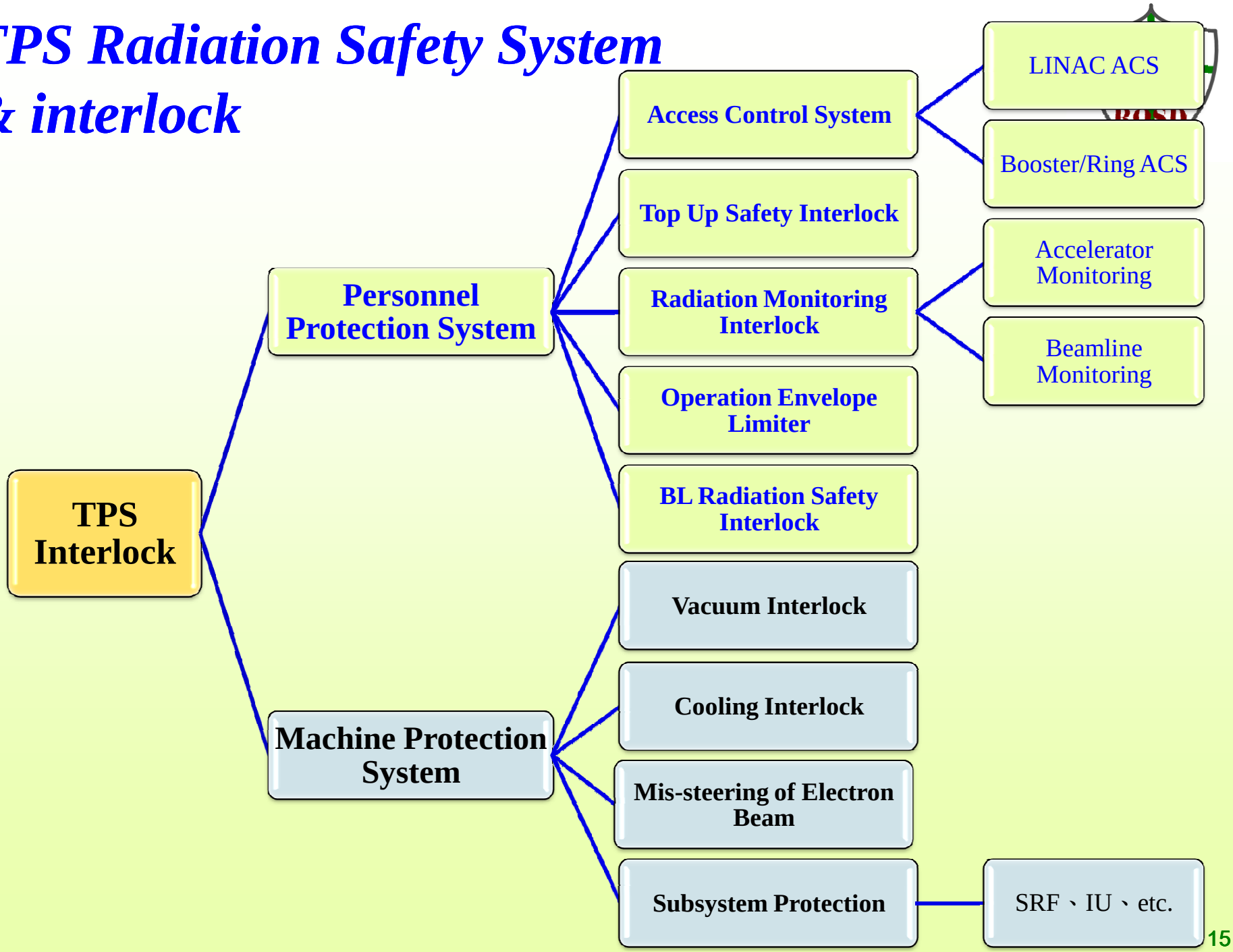




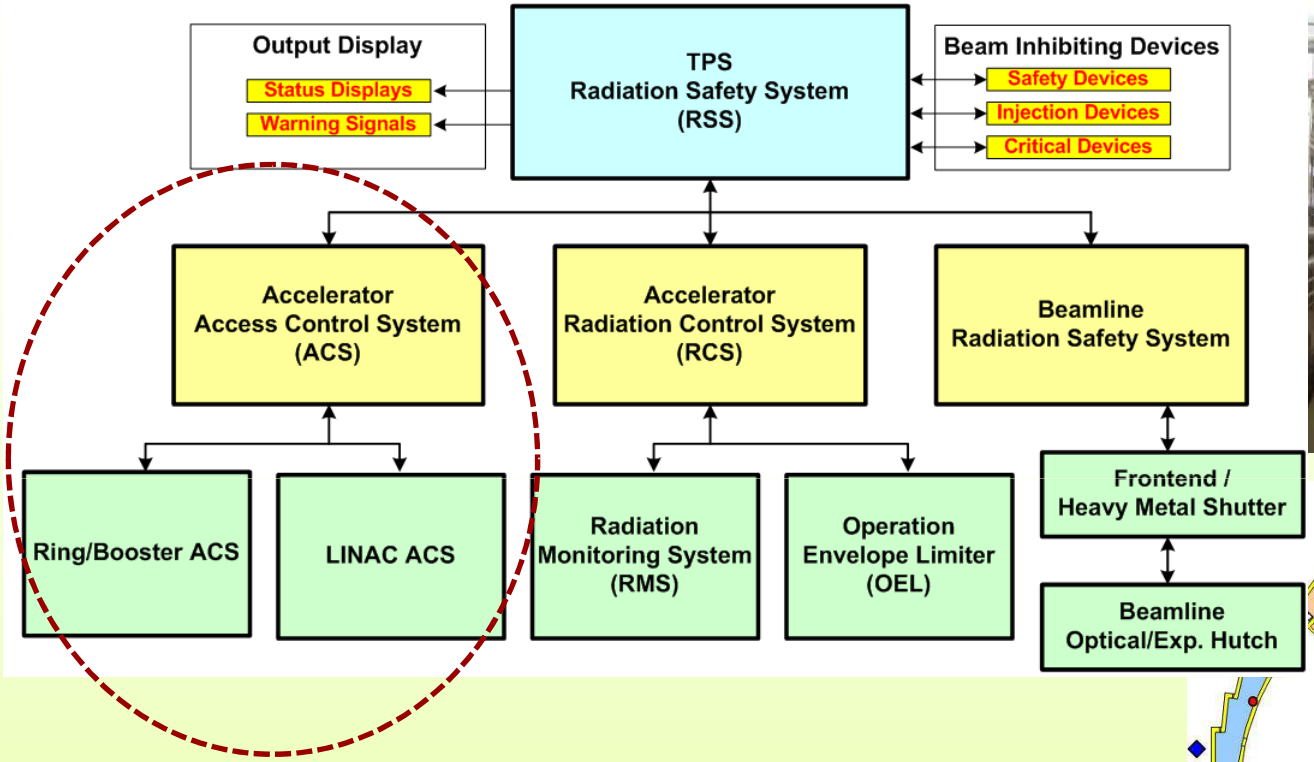
μ Protein Crystallography

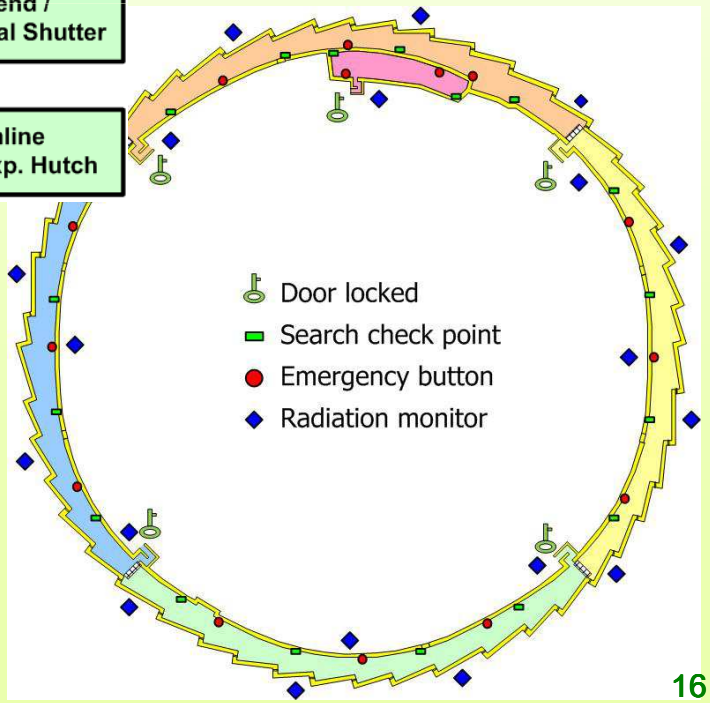
Incoming power 87.3 W
thru FE-slits (worst case)

TPS Radiation Safety System & interlock



Access control system





- Ring divided into 4 sections
- Search sequence
- Emergency shut down mechaniam
- High electric voltage protection
- Oxygen deficiency evaluation for cryogenic leakage

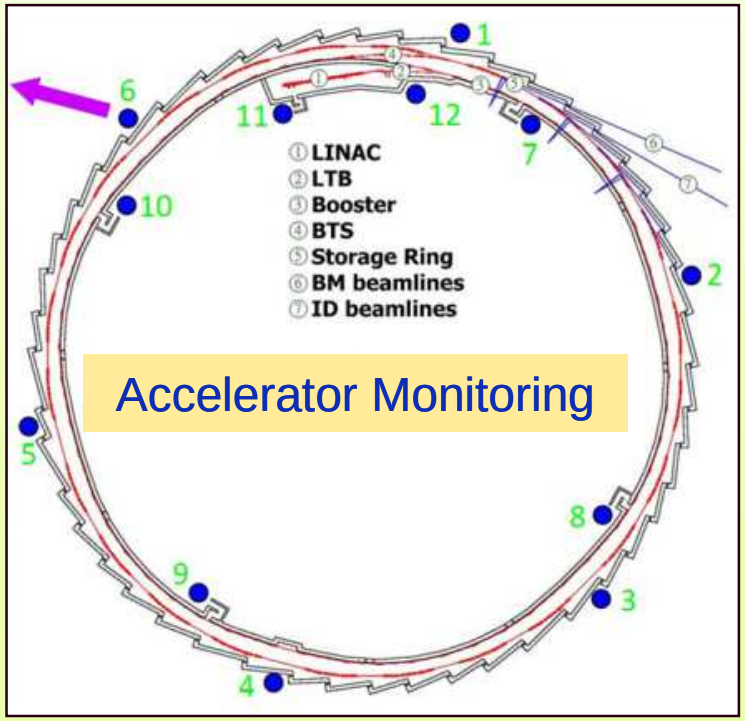
Radiation safety for Top-up operation

Facility	Ray tracing simulation	Minimum current interlock	Dipole setting interlock	Bending magnet in front-end	Interlocked rad. monitoring
TPS	○	○	○		○
TLS		○	○		○
ESRF	○	○			
PETRA III				○	
SSRL	○	○	○	○	○
SPring-8			○		
PLS		○	○		
ELETTRA	○	○	○		
ALS	○	○	○		○
CLS		○			
Diamond	○	○	○		
SOLEIL	○	○			
ALBA		○			
NSLS-II	○		○		○
PF		○	○		
APS		○	○		

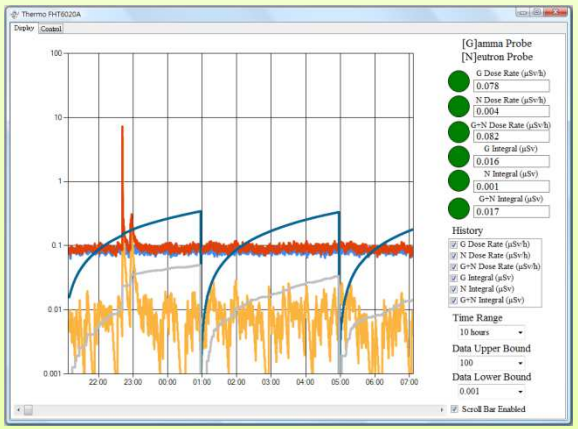
Note: Measures explicitly indicated by each facility are shown.

Radiation monitoring & interlock

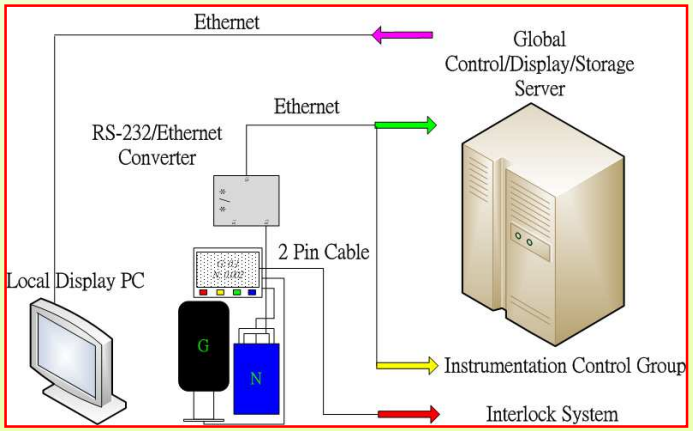
- Annual dose limit 1mSv ÷ 2000 working hours = 0.5 μSv/h
- Accumulating 4 hours, integrated dose (γ+n) ≤ 2 μSv
- Inhibited device:
  - For accelerator: LINAC e-gun & RF
  - For beamline: heavy metal shutter



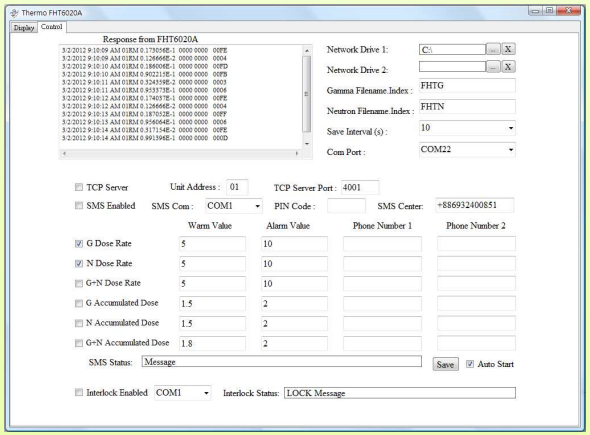
Control scheme and network for radiation monitoring system



Display

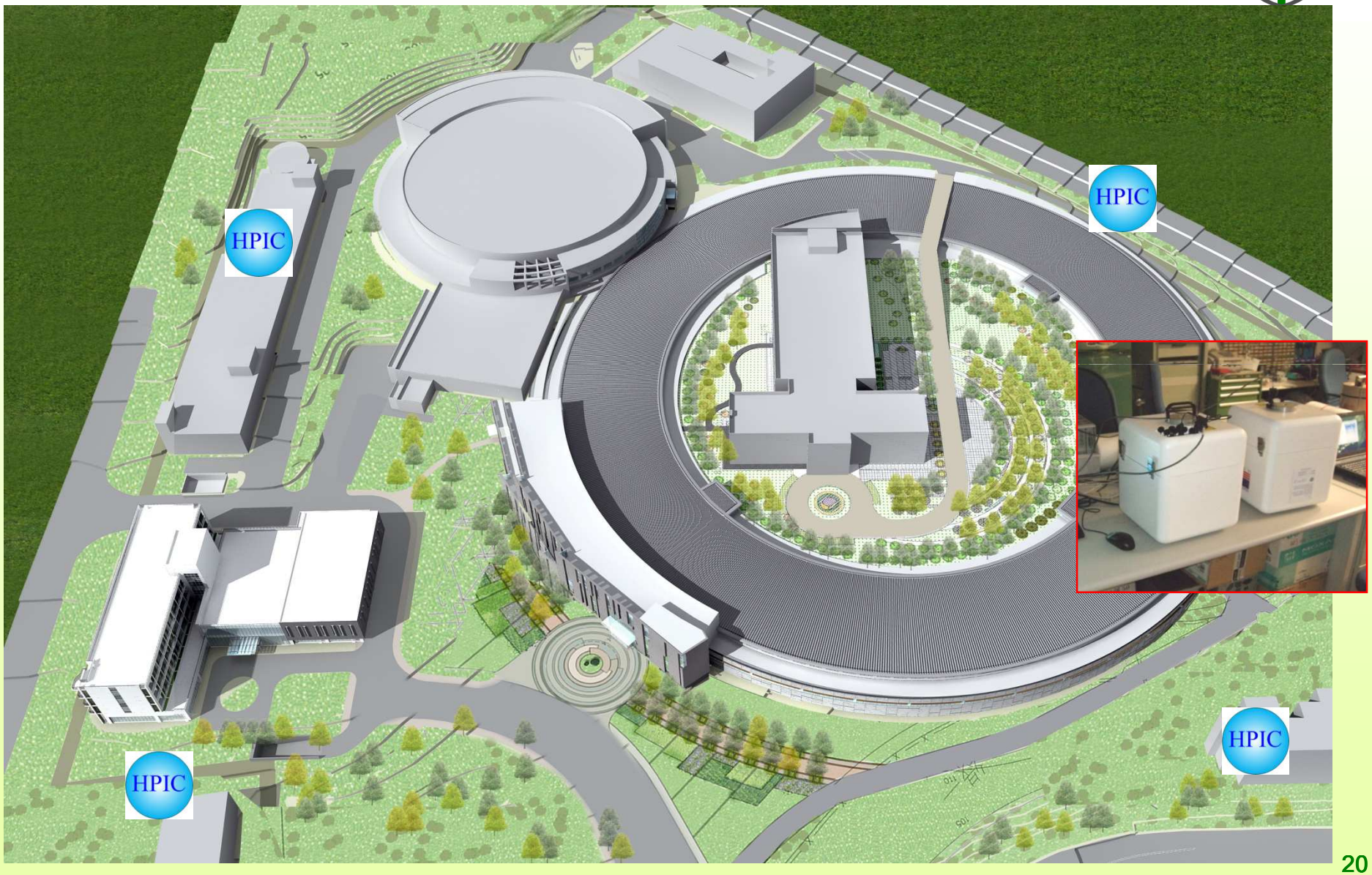


Communication



Control

Environmental monitoring



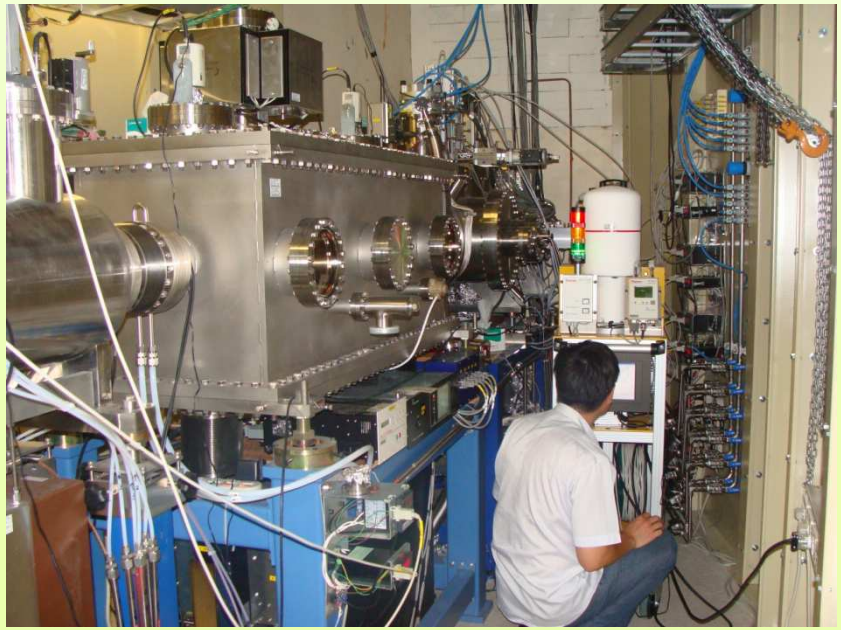
New radiation detectors

- Thermo FHT-191 N ionization chamber
- FHT 762 Wendi-2 Neutron detector (He-3)
- FHT 6020 Display and Alarm Unit for interlock and data logging

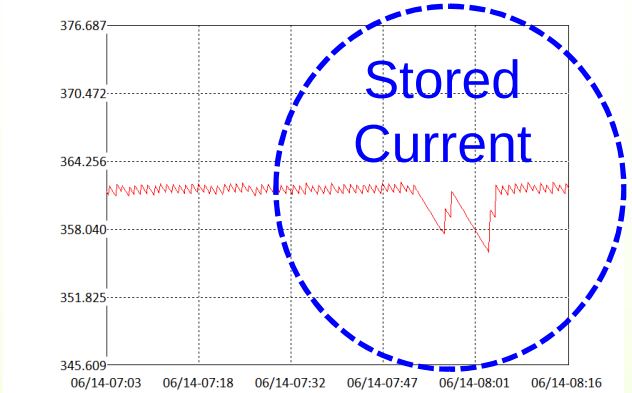
FHT 191 N	Ionization chamber
Measurement Ranges	Gamma dose rate measurement from 10nSv/h up to 10Sv/h
Energy Range	35 keV to 7 MeV
Data Memory	256 periods of selectable length (history)
FHT 762 Wendi-2	**Wide-Energy Neutron Detector**
Measurement Ranges	1µSv to 100mSv/h Cf-252
Energy Range	25meV to 5 GeV according to ICRP 74 (1996)
Sensitivity	Sensitivity: 0.84 cps/(µSv/h) Cf-252 Gamma sensitivity: 1 to 5µSv/h at 100 mSv/h, 662keV

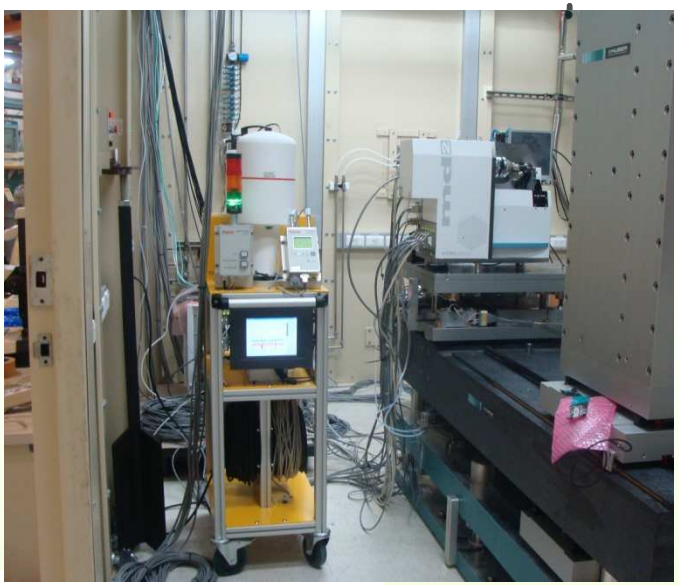
Functional test & comparison

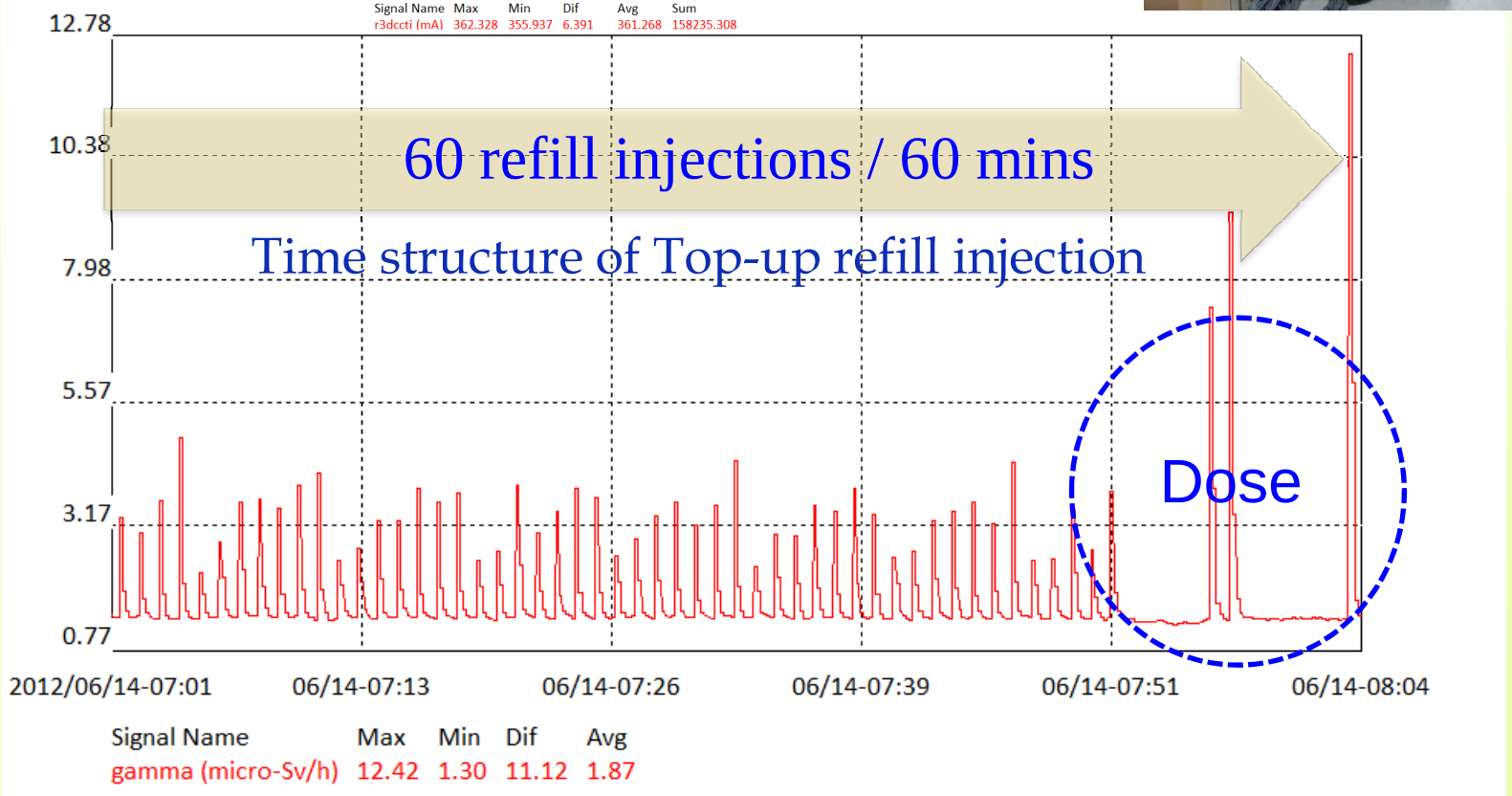
- Various radiation environments
  - 150 MeV LINAC
  - 1.5 GeV TLS
  - Beamline hutch



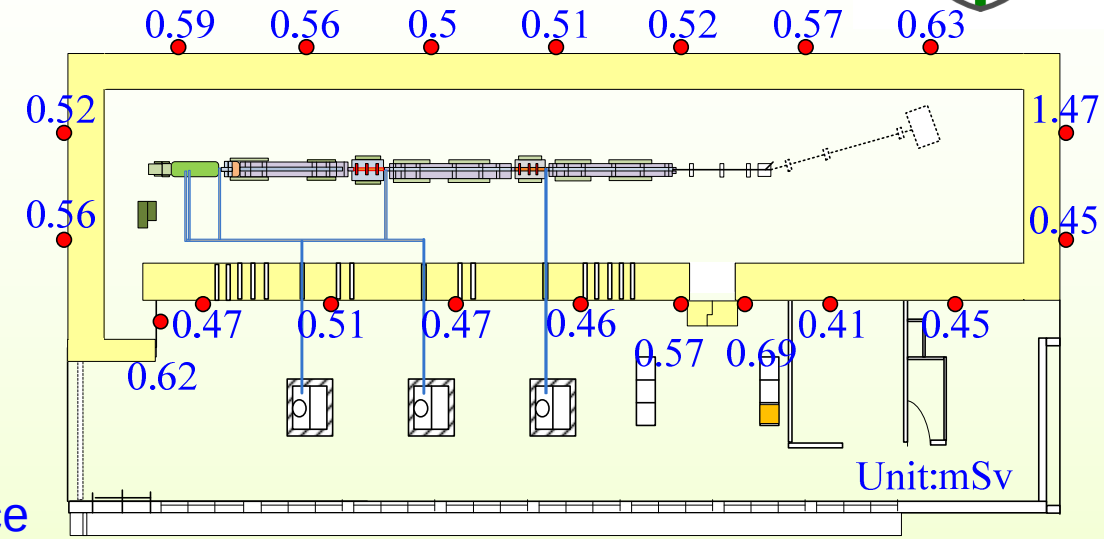
Inside BL15 optics hutch



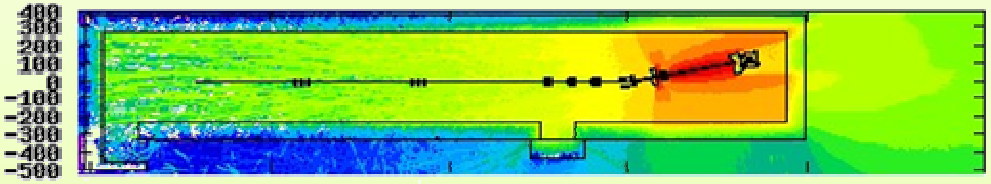




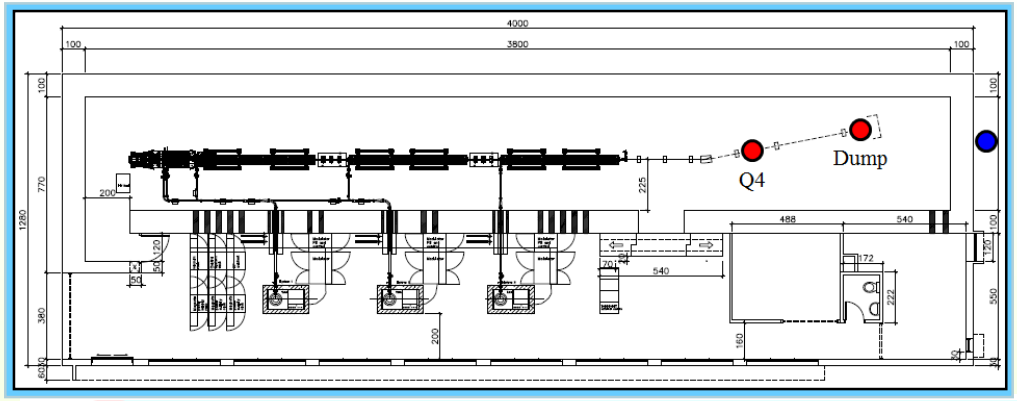
LINAC commissioning



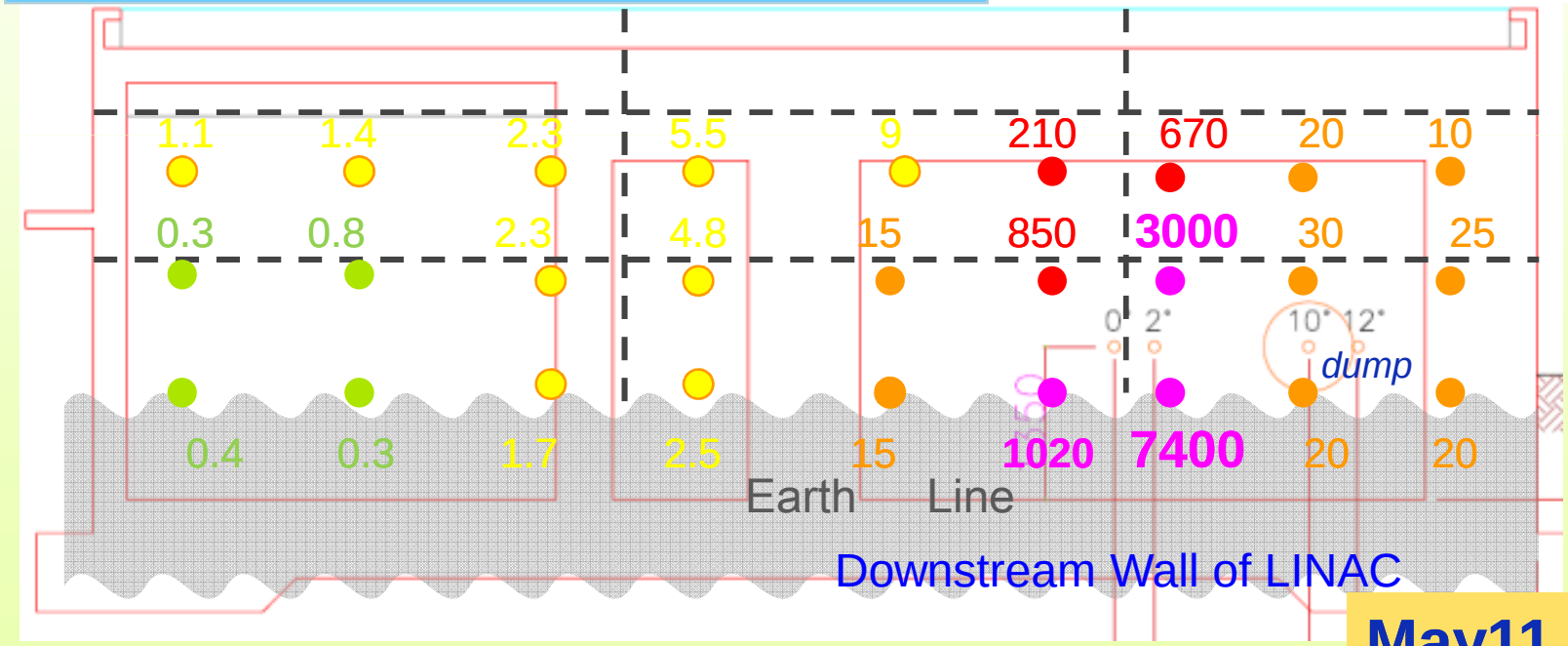
- Preview of TPS rad. safety practice
- Licensing, shielding, monitoring, ACS, survey, simulation and safety control.
- Beam power & workload
- Op. Envelope: 150MeV, 3Hz, 1~3nC



LINAC radiation survey



Parameter	Specification
Bunch train length (μs)	0.2 to 1 (MBM); (SBM_FWHM ≤ 1 ns)
Charge in bunch train (nC)	≥ 5 (MBM) (SBM ≥ 1.5 nC)
Energy (MeV)	≥ 150
Pulse to pulse energy variation (%)	≤ 0.25 (rms)
Relative energy spread (%)	≤ 0.5 (rms)
Normalised emittance (1σ) (πmm mrad)	≤ 50 (both planes)
Repetition rate (Hz)	1 to 5, adjustable
Pulse to pulse time jitter (ps)	≤ 100



>1000 100~999 10~99 1~9 below 1

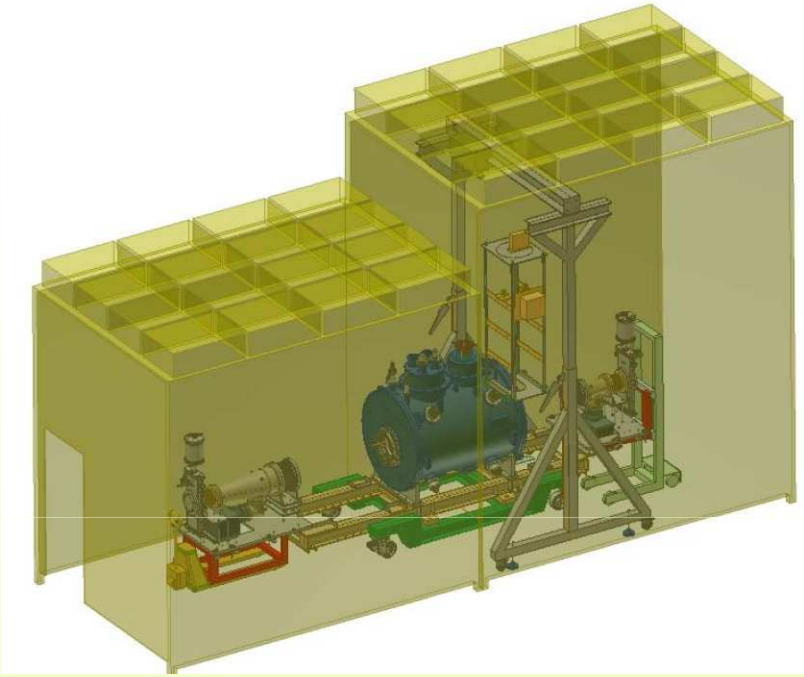
Dose Rate in μSv/h

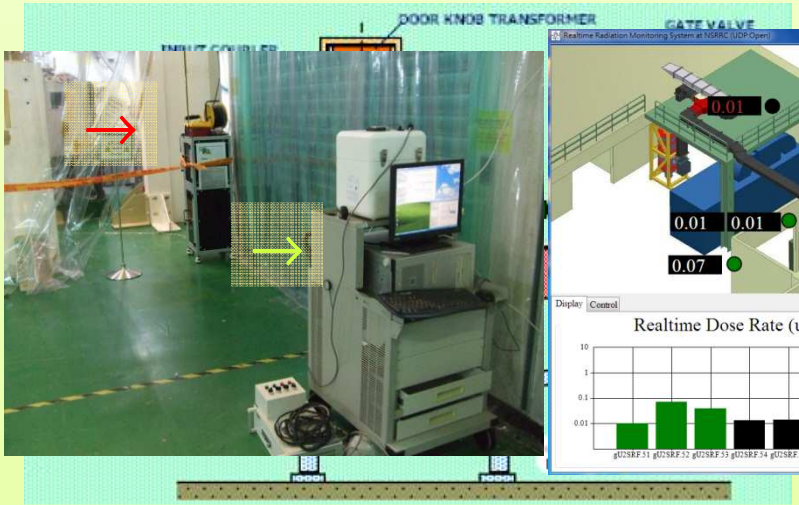
May11, 2011

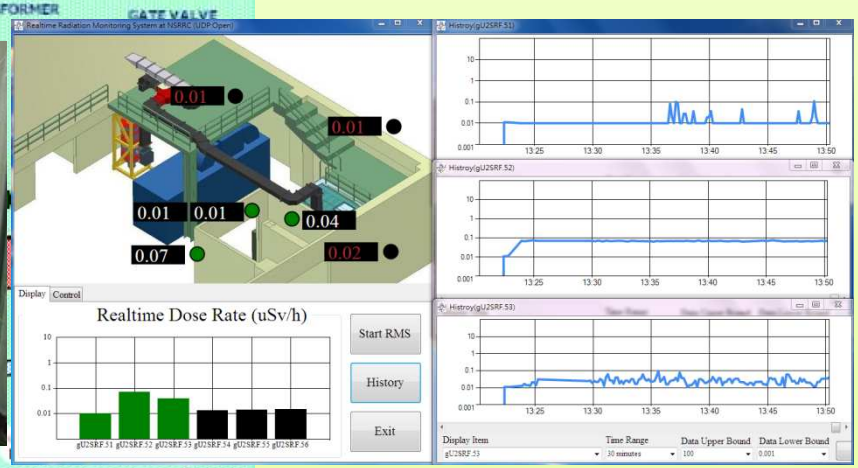
2° to conc. wall

4nC ,150MeV, 5Hz

Conditioning of SRF and survey

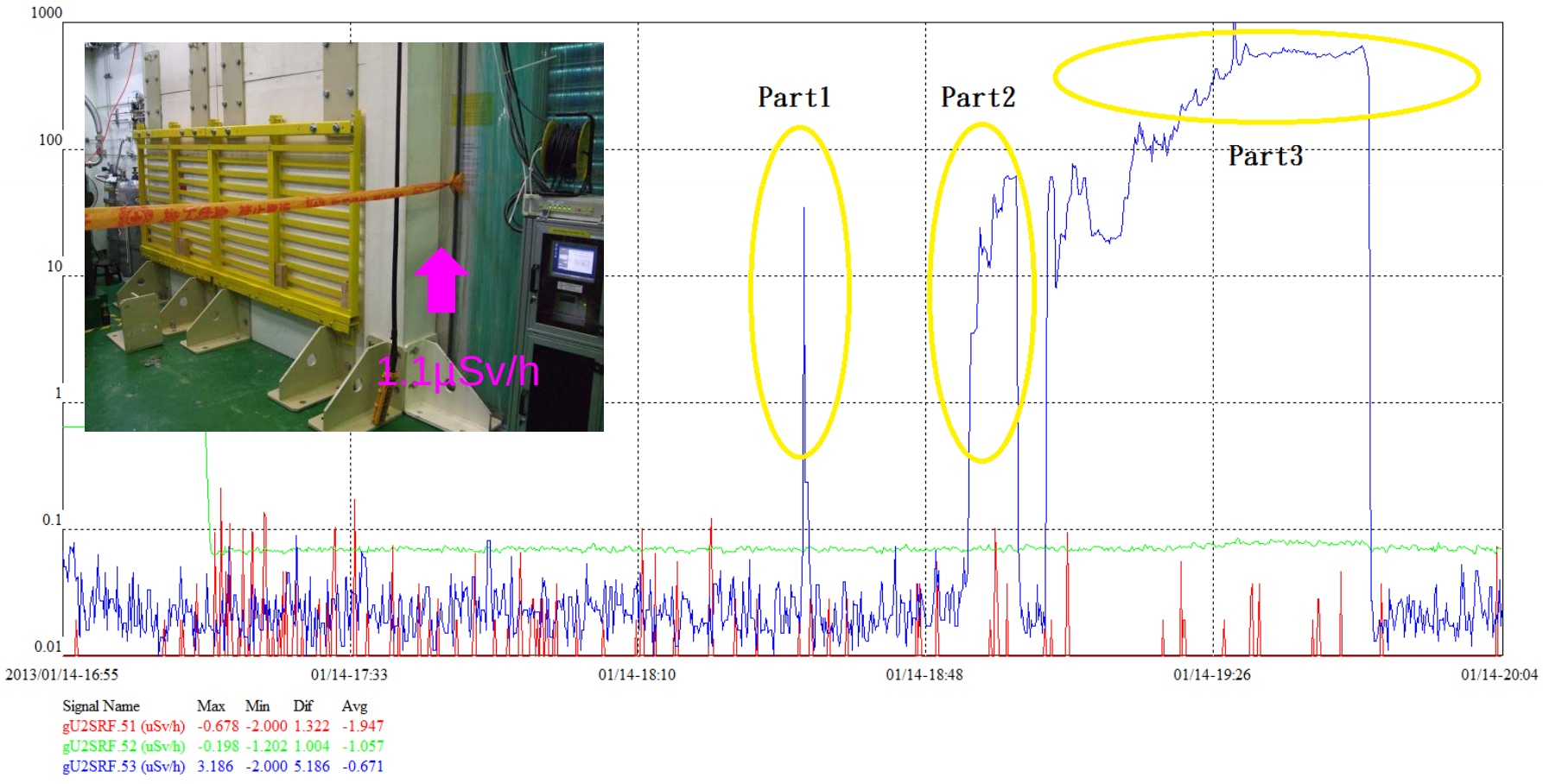






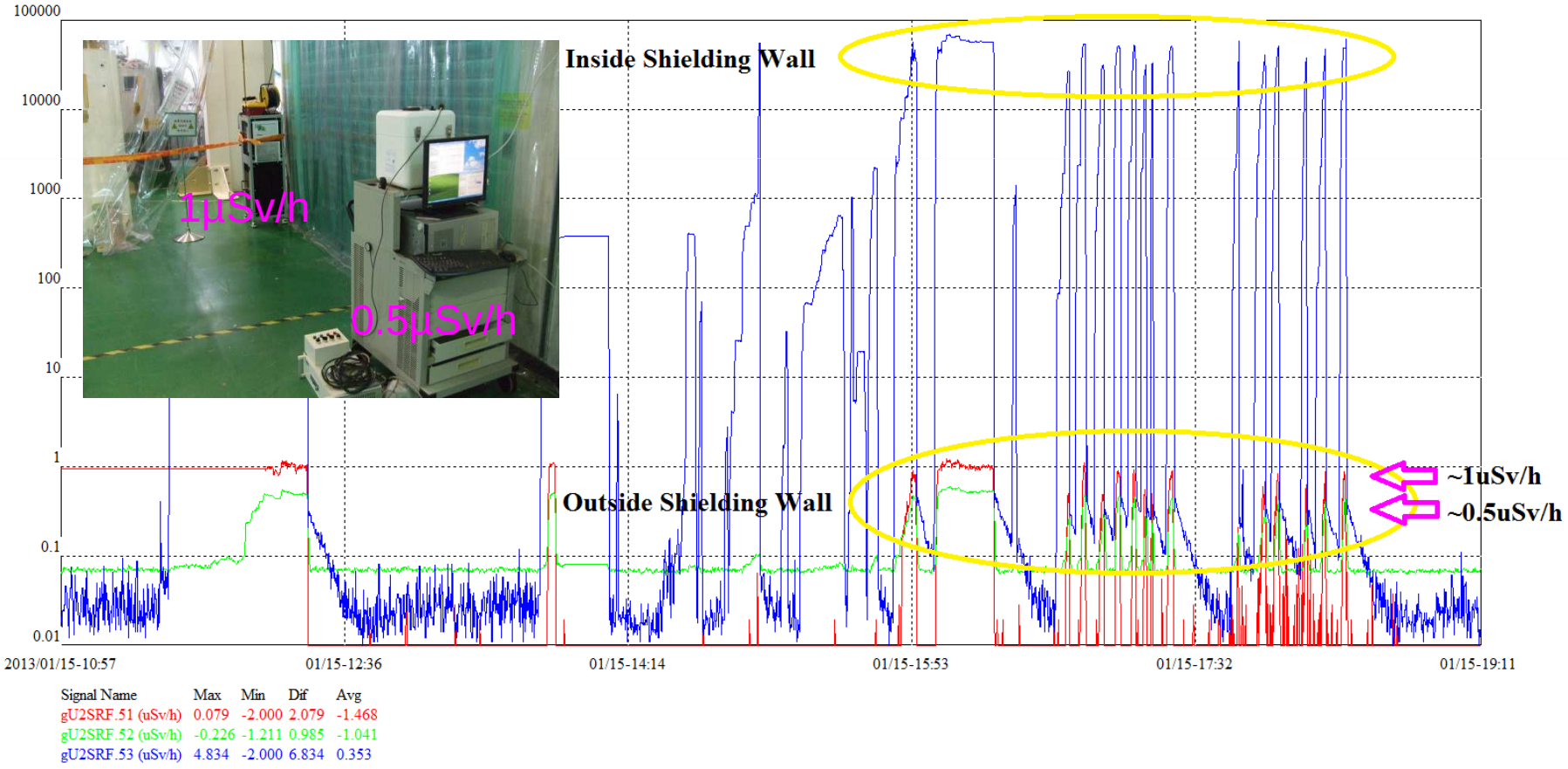
2013/01/14 SRF (110kW,1.6MV)

- Dose ~ 550μSv/h downstream of SRF inside the bunker.
- Dose ~1.1μSv/h at the joint of shielding wall.



2013/01/15 SRF (300kW,2.4MV)

- Dose can easily reach several tenths of thousands at high power.
- Maximum dose 50~68 mSv/h.
- Notable dose at working area

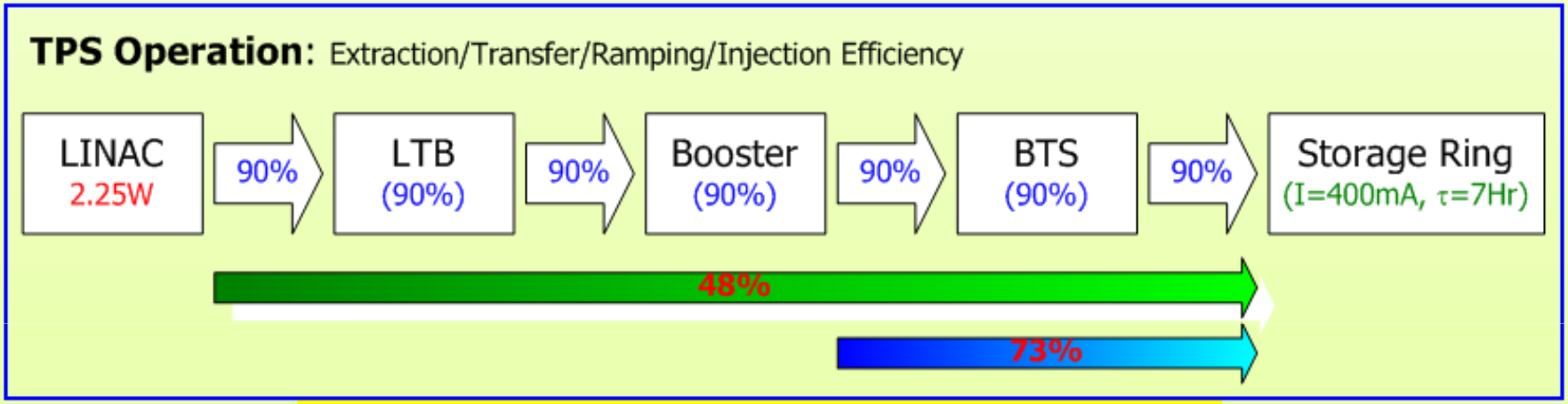


Radiation safety of TPS

- Regulatory requirement:
  - ✓ Exempt of environmental assessment
  - ✓ Review of TPS SAR
  - ✓ Permission of LINAC commission
  - ▪ Permission of TPS commission
  - ▪ Approval of TPS operation
- Responsible system:
  - ▪ Dose evaluation and safety assessment
  - ▪ Shielding design for accelerator and beamline
  - ▪ Monitoring network and interlock
  - ▪ Access control system
  - ▪ Radiation safety interlock
  - ▪ Toxic waste disposal facility
- Operation coordination:
  - ▪ Safety audit on civil construction
  - ▪ Interface discussion for interlock
  - ▪ Radiation safety control on commissioning
  - ▪ Industrial hygiene of installation

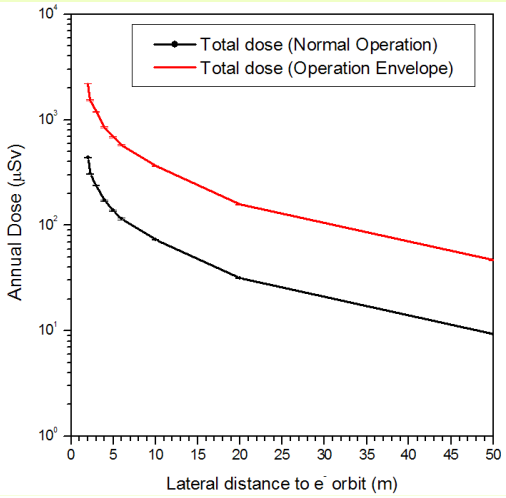
The end

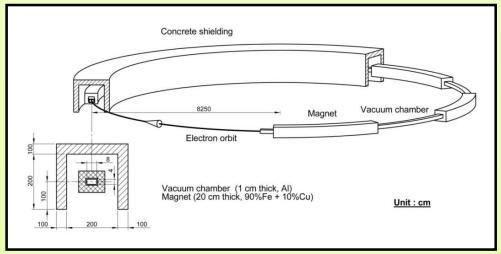
Operation Envelope



Reference Beam Loss → Operation Envelope → Safety Envelope

Effect of stored current & beam lifetime





Max Annual Dose for 2000 hours near Shielding Walls [mSv/y]

Tau\I	100	200	300	400	500 [mA]
20	0.09	0.18	0.28	0.37	0.46
18	0.10	0.19	0.29	0.39	0.48
16	0.10	0.21	0.31	0.41	0.52
14	0.11	0.22	0.33	0.45	0.56
12	0.12	0.24	0.37	0.49	0.61
10	0.14	0.28	0.41	0.55	0.69
8	0.16	0.32	0.48	0.64	0.80
7	0.18	0.35	0.53	0.71	0.88
6	0.20	0.40	0.60	0.79	0.99
5	0.23	0.46	0.69	0.92	1.15
4	0.28	0.55	0.83	1.10	1.38
3	0.35	0.70	1.05	1.41	1.76
2	0.50	1.01	1.51	2.02	2.52
[hour]					