10 YEARS OF SAFE OPERATION AT THE CANADIAN LIGHT SOURCE – A RADIATION SAFETY PERSPECTIVE

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RADSYNCH15

DESY

Hamburg, Germany.

June 4, 2015

The Canadian Light Source

Outline

- **CLS Facility Description**
- **Radiation Safety Program**
  - Federal Regulations
  - Design
  - Operations
  - Access Control and Interlock
  - Shielding
  - Radiation Monitoring
  - Medical Isotope Program
- **Future**
  - Top-Up Operation
  - Personal Dosimetry Requirements

1999


3.32 Hectares located on
University of Saskatchewan Campus

Saskatoon – the advantage of co location

Highlights/Firsts

- 1999: Formal funding announcement; Start of construction.
- 2001: Main experimental hall building construction is complete and ready for occupancy. LINAC upgrade commissioning underway.
- 2002: Start of commissioning the booster ring. (The 2.9 GeV electrons produced are the highest energy achieved by any Canadian particle accelerator to date)
- 2003: Start of commissioning the main storage ring.
  - First synchrotron light detected in the Optical Diagnostics Beamline.
- 2004: First x-rays detected in the SGM Beamline.
  - Commissioning of the storage ring is completed.
  - First experimental data recorded on the SGM Beamline.
  - Official Grand Opening.
- 2005: First synchrotron user!!

Electron Gun

- 2 Stories undergound
  - Former SAL
- 220 kV Operating Voltage
- 60 mA Average Current
- 1Hz

LINAC

- 6 Section Linac
- 70 or 140 nS pulse
- 250 MeV
- Energy Compression
- Linac-to-Booster (LTB)
  - 70 meters long
  - Up two floors

Booster Ring

- 250 MeV to 2.9GeV
- 10 mA design average operating operating current
  - 3 to 4 mA normal
- 20 dipoles
- 28 quadrupoles
- 2 RF cavities

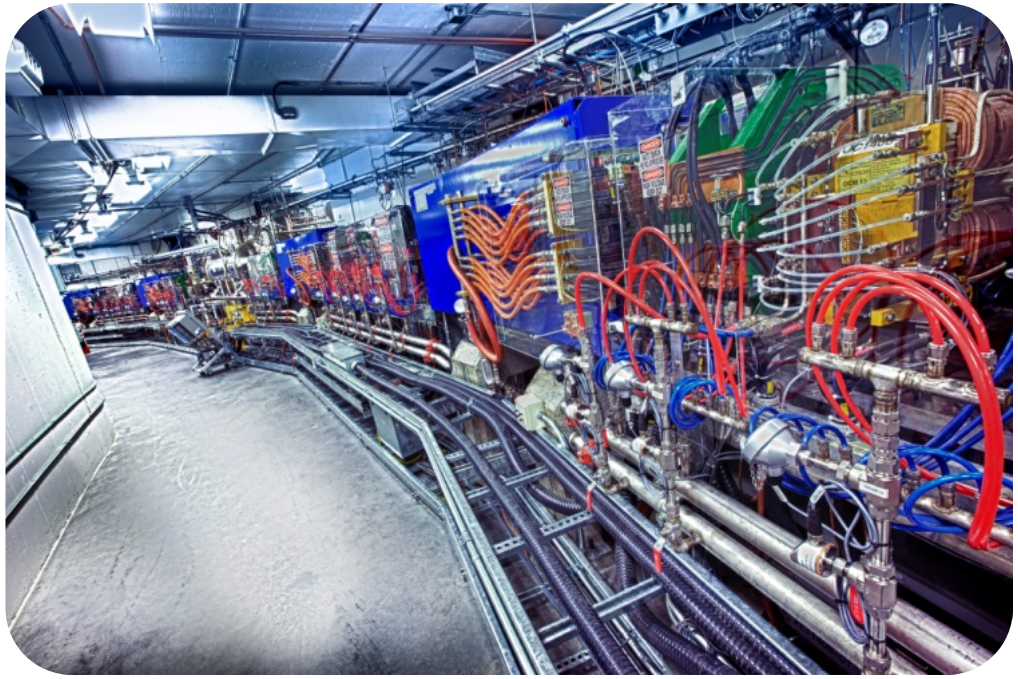
Storage Ring

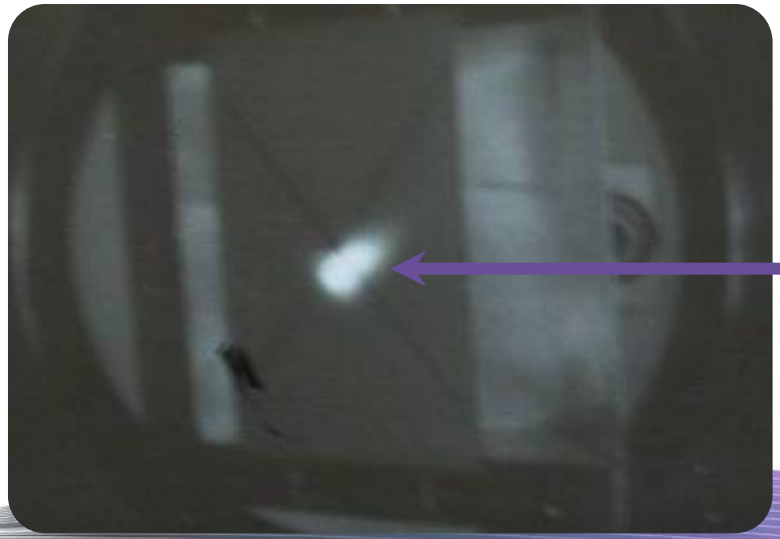
- 24 Dipoles
- 12 straight sections
  - 9 available for insertion devices
- Superconducting RF cavity
- 2.9 GeV
- 171 meters diameter

Beamlines

- 14 Operational Beamlines
- 2 diagnostic beamlines
- 7 commissioning or under construction
- Infrared to Hard X-ray

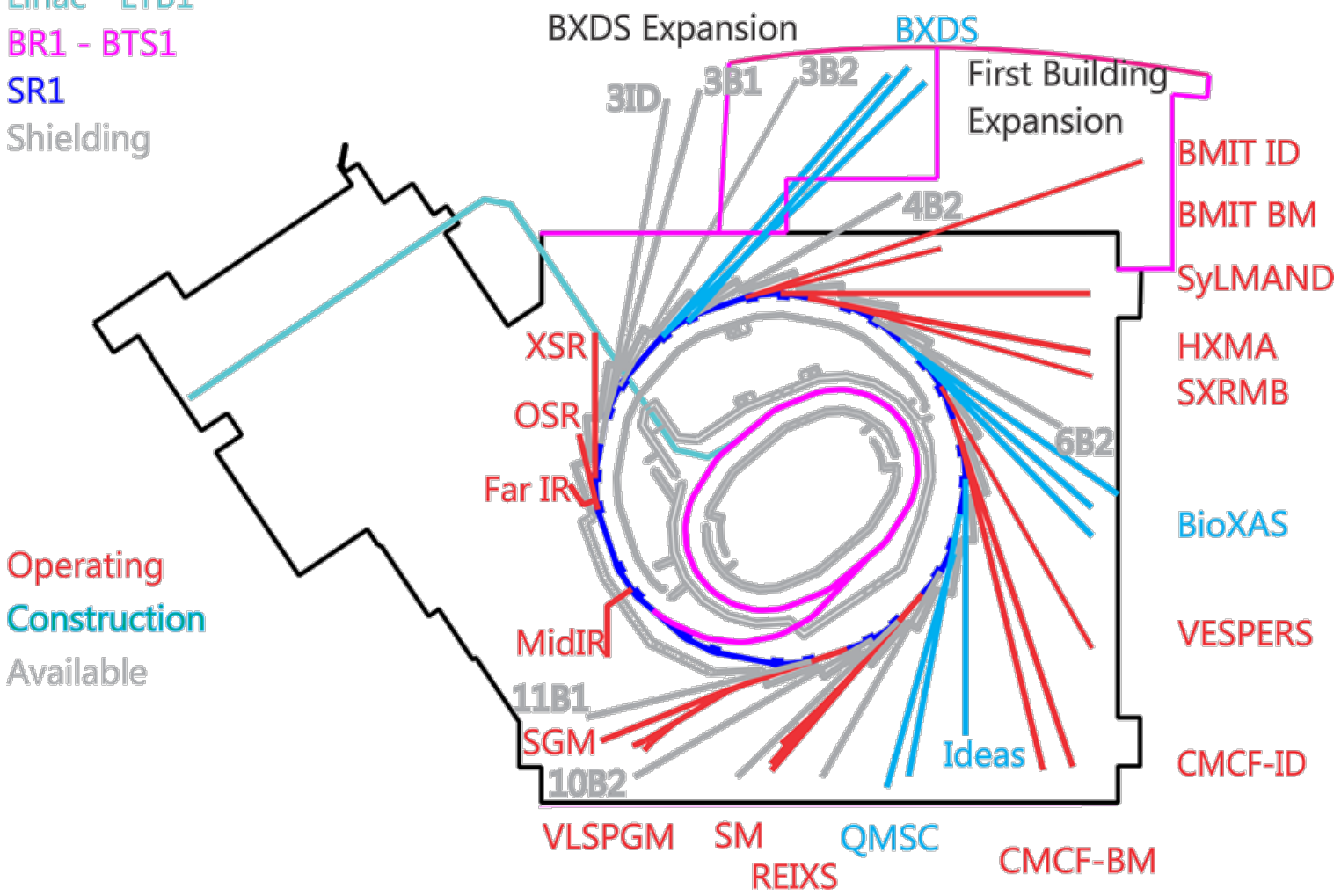
Booster & Storage Rings



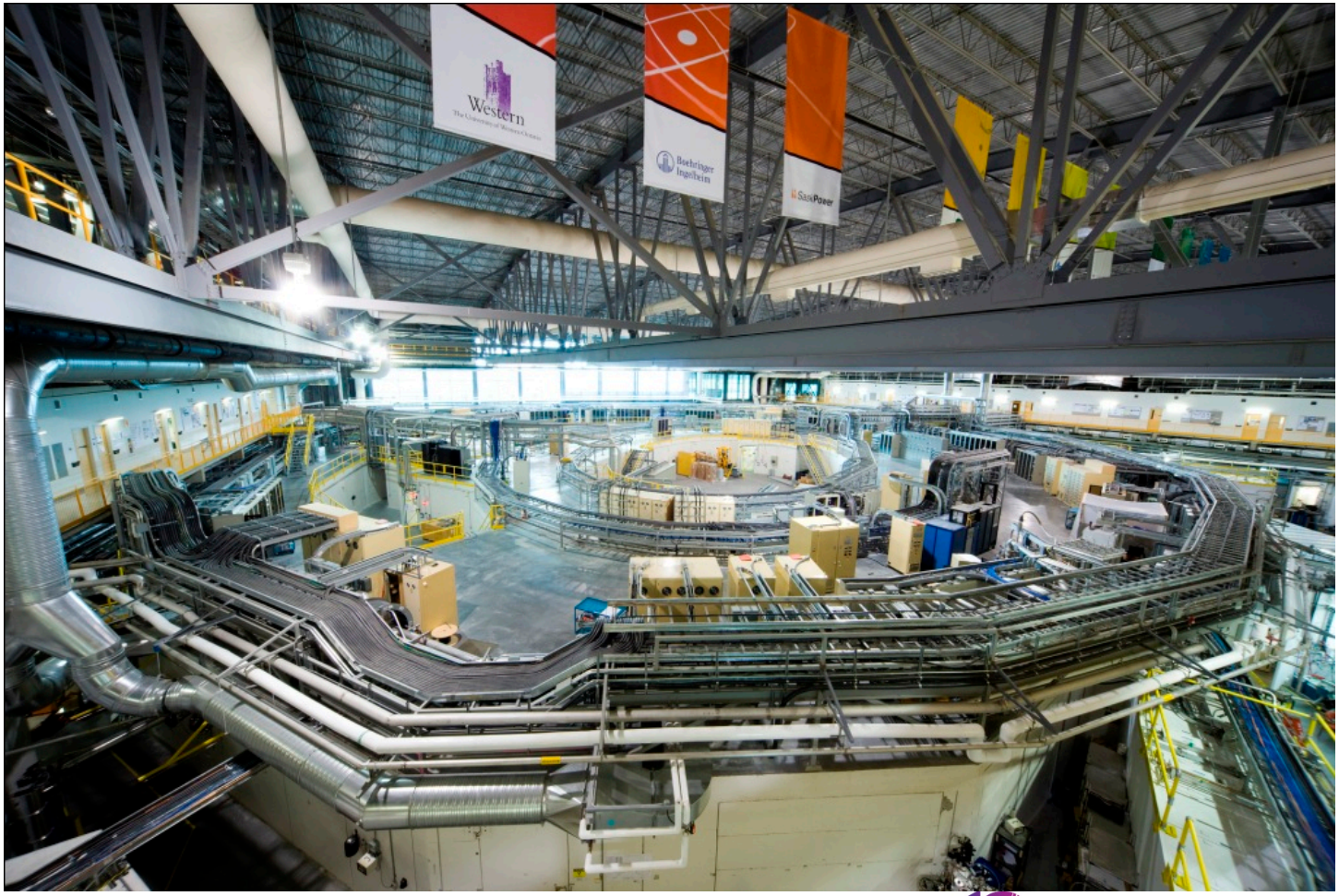


Electron stream

Inside the CLS



Inside the CLS



Canadian Light Source | Centre canadien de rayonnement synchrotron

TEN YEARS OF DISCOVERY

CANADIAN REGULATIONS

- Canadian Nuclear Safety Commission (CNSC)
  - Creates regulations
  - Grants licenses for nuclear facilities
  - Oversees compliance
  - Class 1B Licence
    - U mines
    - U Fuel Fabrication
    - Waste Disposal
    - Using or processing $>10^{15}$ Bq other than U fuel
    - > 50 MeV accelerator

- Safety Case
  - Licence Condition Handbook
  - Radiation Protection Program

RPP – Facility Design

- **CLS Regulatory Design Basis**
- CLS Nuclear Energy Worker (NEW) 10 mSv
  - One-year dosimetry period
  - CNSC 50 mSv

- CLS Non-NEW 1 mSv
  - Employees, Users, Contractors
  - One calendar year
  - Member of the public

- Worst case accident dose 1 mSv

RPP – Facility Design

- **CLS Operational Design Considerations**
- Linac
  - 250 MeV
  - 1 Hz

- Booster Ring
  - 2.9 GeV Max
  - 10 mA average current
  - Dose rate in RCA from injection max 80 µSv/h
  - 15 minutes of injection time every 4 hours

- Storage Ring
  - 2.9 GeV Max
  - Dose rate max of 5 µSv/h in CAZ
  - 500 mA max stored current
- Beamlines
  - 2 µSv/h
    - Bremsstrahlung + Synchrotron (1+1)

Design Philosophy

- 0.5 µSv/h ??
- 5 µSv/h X 2000 h/year = 10 mSv
- (@30 cm from outer wall)
- Build to meet minimum
- Add local shielding where required
- Verify
- ALARA
- Defense in Depth

Current Operation

- 250 mA stored beam in normal mode
  - 1 superconducting cavity installed
- Injection < 10 minutes every 12 hours

Shielding Design

- Initial accelerator shielding based on
  - IAEA 188 (Swanson)
  - H.G. Moe et al

$$H_B(\theta_B) = 0.167\, E_o\, (2^{-\theta_B/\theta_{1/2}}) + 8.33\, (10^{-\theta_B/21}) + 0.25\, (10^{-\theta_B/110})$$

$$D = 3600 \times P \times \sum_i \left(\frac{H}{r^2} \times e^{\left(-\rho d / \lambda_i\right)} \right)$$

- beamline shielding
  - STAC8, TVdose
  - EGS

Commissioning

- Optimization of Operation and Safety
- Only commissioning team allowed during machine commissioning
- Evenings + Overnights

- LINAC
  - Completed in 2002
- BR1
  - Completed in 2003
- SR1
  - Completed in 2004
- Beamlines
  - Ongoing (neverending?)

COMMISSIONING

- Beamlines
  - Commissioning plan
  - Detailed radiation surveys
  - Primary Enclosure (White beam) vs Optical Enclosure (monochromatic beam)
- Changes to accelerator
  - New components
  - Design changes

Bulk Shielding

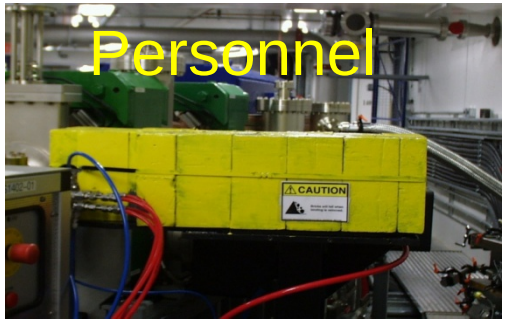
Bulk shielding at CLS

Storage Ring Outer Wall

Beamline Enclosure

SHIELDING

- Local Shielding
- Master Shielding Drawing and checklist
- Shielding checks performed prior to start up after extended shutdown
- Personnel Protection vs Machine Protection
- Some Shielding Interlocked

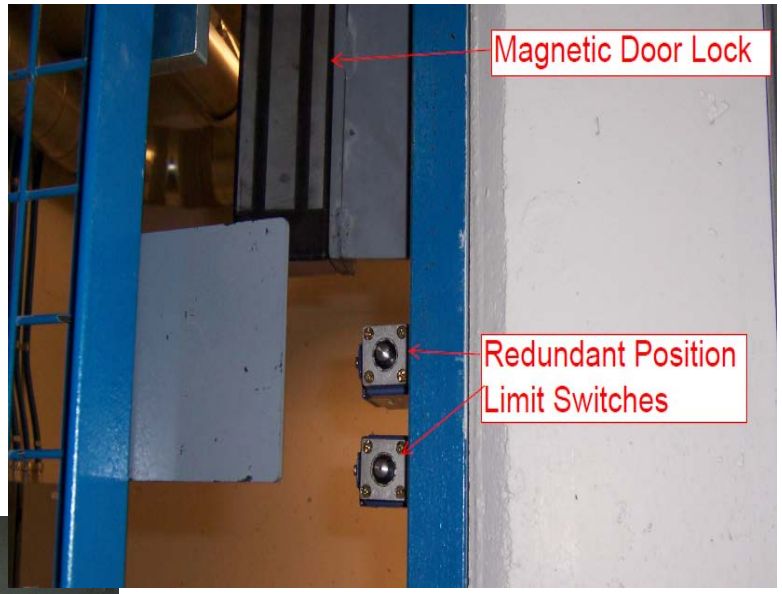


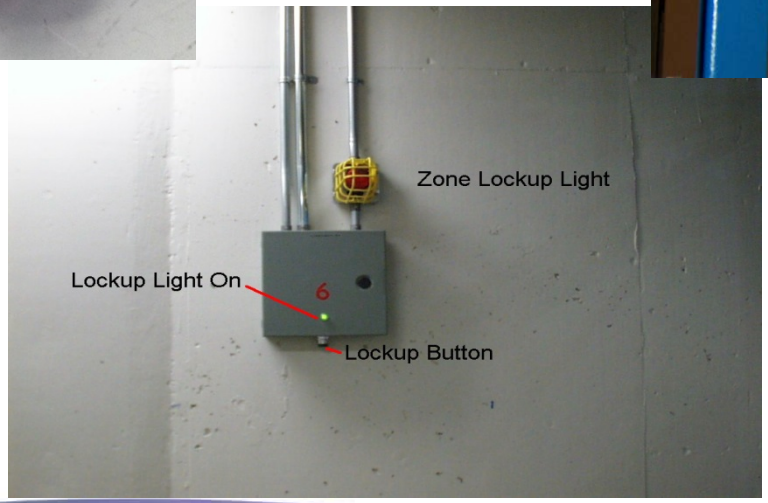
ACIS

- Access Control and Interlock System (Personal Protection System)
- Accelerator, beamlines
- Design
  - Redundant and independent radiation source shut-off systems
    - E Gun
    - Linac, Booster Ring Storage Ring RF
    - Front End Safety shutters
  - Relay based system + Safety rated PLC system
- Testing
  - Commissioning
  - Annual V&V
- Training
  - Provided to staff by HSE
  - Users trained as part beamline specific training

ACIS


BEAM OFF
EOS1304-07


Magnetic Door Lock
Redundant Position
Limit Switches


Zone Lockup Light
Lockup Light On
6
Lockup Button

RADIOACTIVE MATERIAL

- Sealed Sources – check sources
- Activated material (procedure for storage and release)
- Radioactive samples and beamlines
  - limited to mostly use of low level U tailings to date.

RADIOLOGICAL MONITORING

Personnel Monitoring

- All staff NEW at first
  - Everyone working at CLS assigned a dosimeter
  - Gamma + Neutron
  - Exchanged quarterly
  - EPD for special situations (tours, HRA work, residual survey not complete)
  - Action levels 2.0 mSv for NEW
  - Internal Admin level 0.6 mSv
  - 0.2 mSv for non-NEW

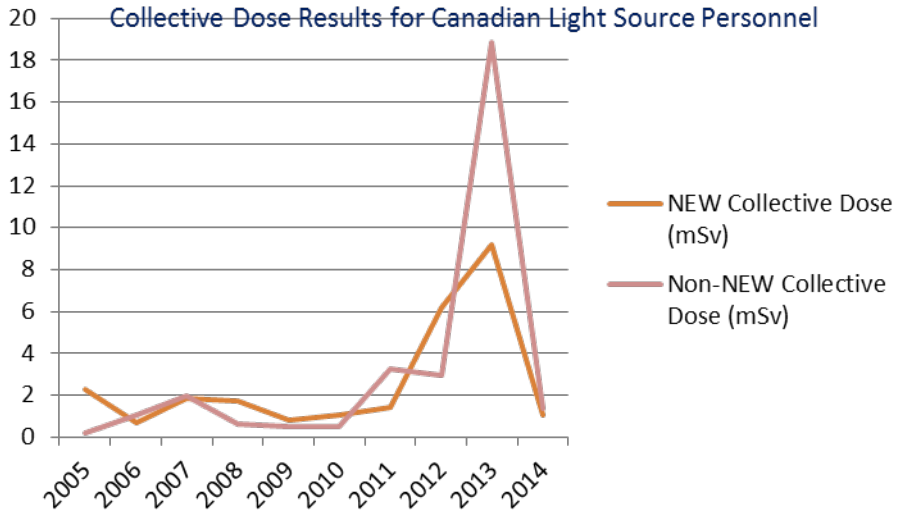
Plan to remove Luxels from Users/Admin staff in future.

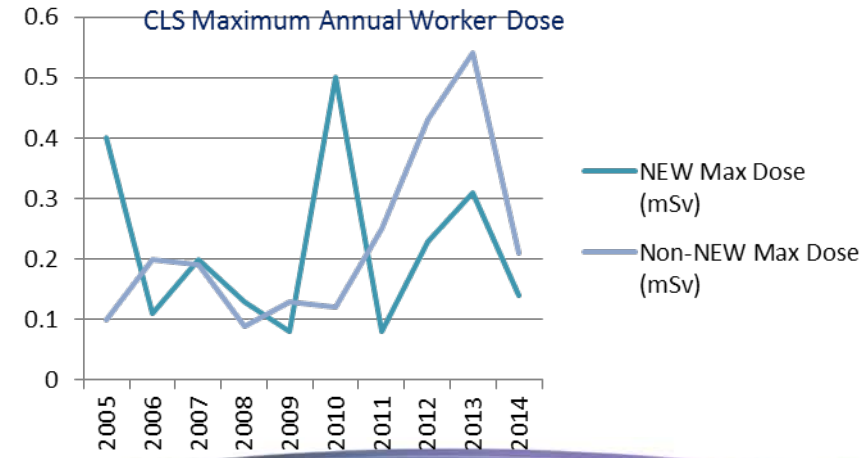
Radiological Monitoring

Personal Dosimeter

Electronic Personal Dosimeter

Personal Dosimetry





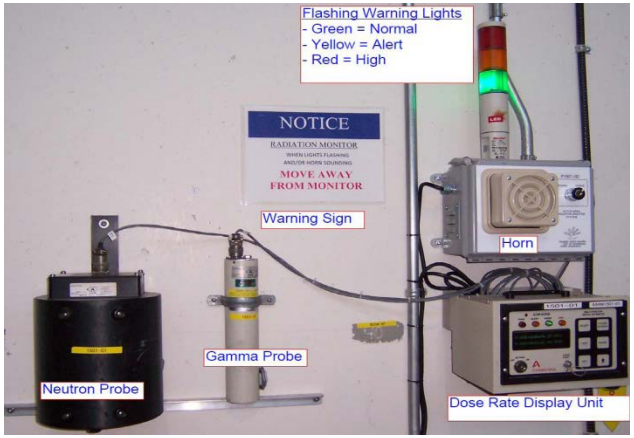
- Collective doses to all workers low
- Max dose has never exceeded public limit for any worker
- Background issue in 2012 resolved
- 2013 elevated levels due to in transit irradiation of dosimetry shipment
- No personal neutron dose recorded
- > 95% dosimeters with no dose

RADIOLOGICAL MONITORING

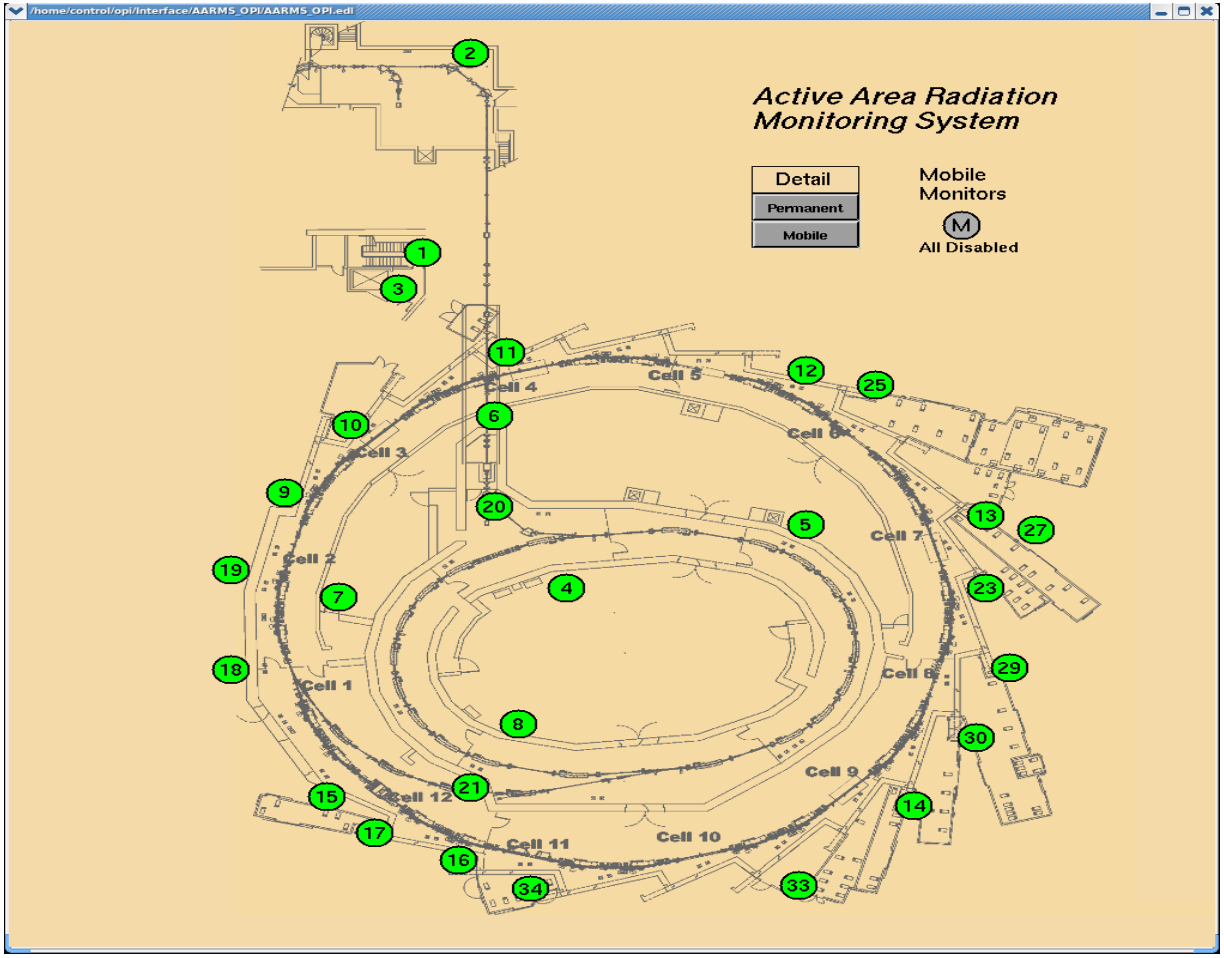
- Passive Area Monitoring
  - Luxel- some with Neutrak (CR-39) chip
  - throughout facility (>500 locations)
  - Exchanged quarterly

RADIOLOGICAL MONITORING

- Active Area Radiation Monitoring System (AARMS)
  - Canberra ADM, IP-100, NP-100 (BF_3, He)
  - 2.5 µSv hourly cumulative dose interlock
  - 50 µSv/h µSv/h
  - 100 µSv/h alarm



Active Radiation Monitors



RADIOLOGICAL MONITORING

- Prompt Radiation Surveys
  - Performed regularly on
    - Storage Ring
    - Beamlines
    - Injection vs stored beam
- Residual Radiation Surveys
  - Performed prior to extended shutdowns or when required for special work
  - Machining radioactive material

RADIOLOGICAL MONITORING

Ludlum 2360 alpha/beta Counter

Thermo FH40G-L10

Exploranium GR-130 Gamma Spec

Ludlum 9DP

RADIOLOGICAL WORK

- Machining Radioactive Material
  - Very little demand
- High Radiation Area Work
  - Uncommon in CLS
  - Common in MIP
- Contractors in Radiological Control Areas
  - Very common
- HSE Department
  - Sealed source use
  - Radiation surveys

RADIOLOGICAL MONITORING

- Contamination Surveys
  - Performed routinely throughout facility
  - Beamline radioactive material experiments
- Accelerator Cooling Water Analysis
  - Performed routinely

TRAINING

- Radiation training requirements determined by type of work and access requirements
- Radiation Awareness Module - Basic level training for Users
- General Radiation Training – Non-NEW CLS staff and contractors
- Radiological Worker Training – NEW
- Worker/specialized Training (ACIS Lockup, Survey, Sealed Source Use, other)

Events

- **Magnet Event**
  - Upgrade to transfer line power supplies resulted in bend magnet polarity reversal
  - Radiation alarm of 82 µSv/h in RCA
  - No exposure to any worker
  - Improvements to work management resulted

- **Punctured Fe-55 source (3.43 MBq)**
  - Loss of 0.7 MBq determined
  - No dose
  - Improved handling procedures resulted

Medical Isotope Project (MIP)

Accelerator based production of Mo-99 from Mo-100.

- 35 MeV (40 kW) 3 section linear accelerator
- Production currently 20 kBq per week
- Clinical trials to start in fall of 2015
- Larger scale production facility planning underway

Mo-99 → Tc-99 for medical imaging

Future Challenges

- Top-Up Operation
  - Planning started in 2012
  - Leadership + staffing changes delayed
  - Now not an ‘official priority’, but much interest
  - 2017?

- Staff Dosimetry
  - Dose results historically low
  - Re-evaluation of dosimetry requirements for CLS staff 2016

Thank you. Questions?