# Radiation safety risk matrices at MAX IV and other synchrotron light sources

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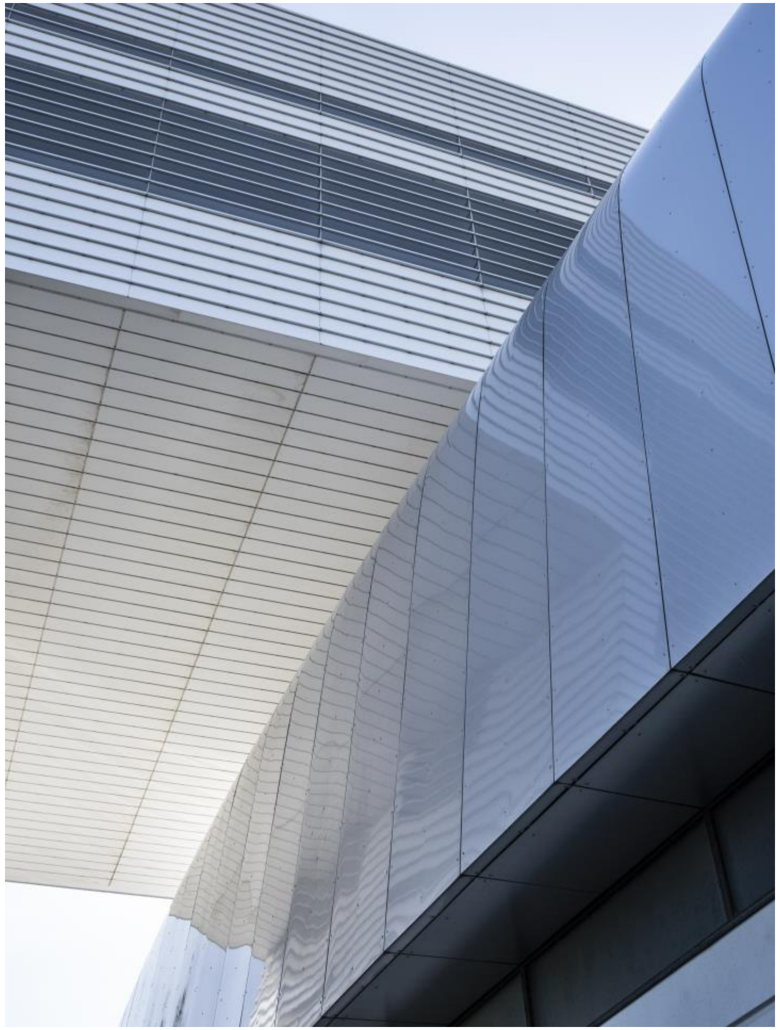
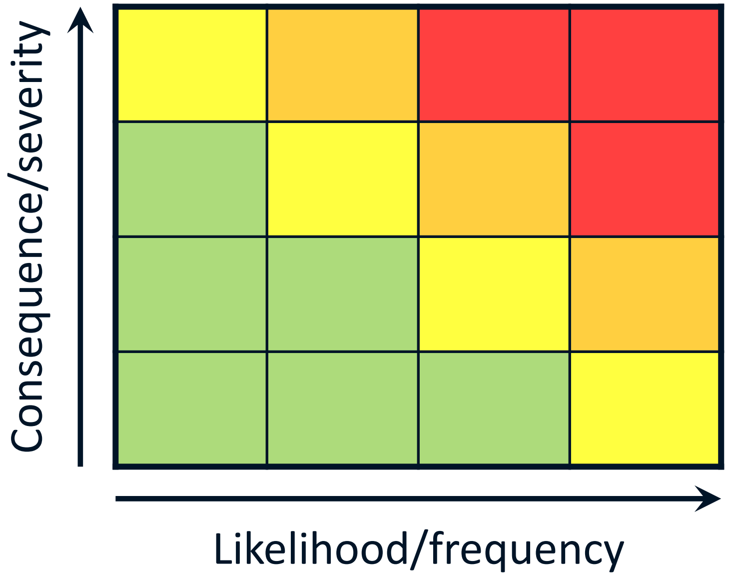


# Introduction

# Risk matrix

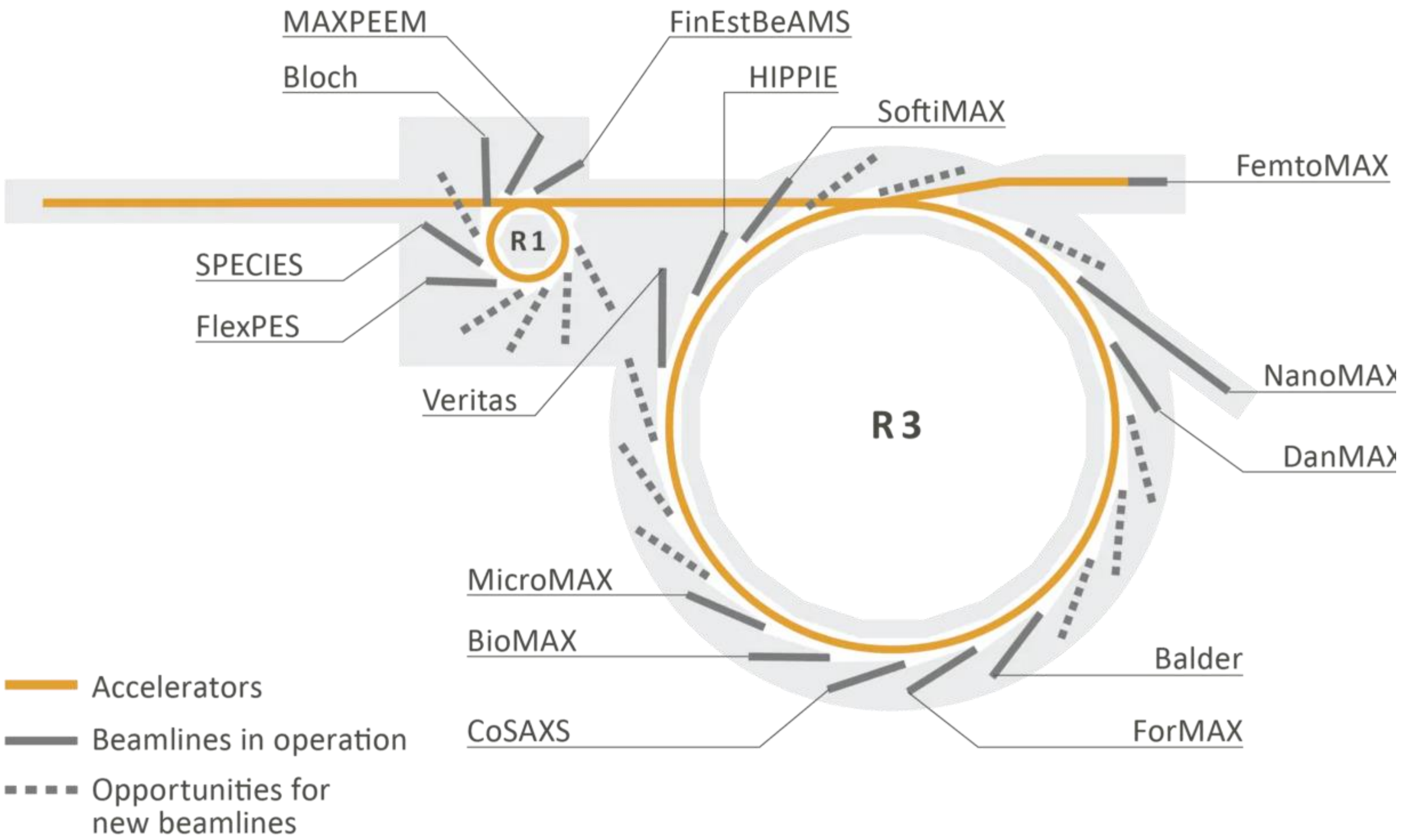
A risk matrix is a tool used in risk assessment to visualize and prioritize risks by combining the likelihood of an event occurring with its potential consequence or severity. It uses discrete categories of consequence, likelihood, and risk.

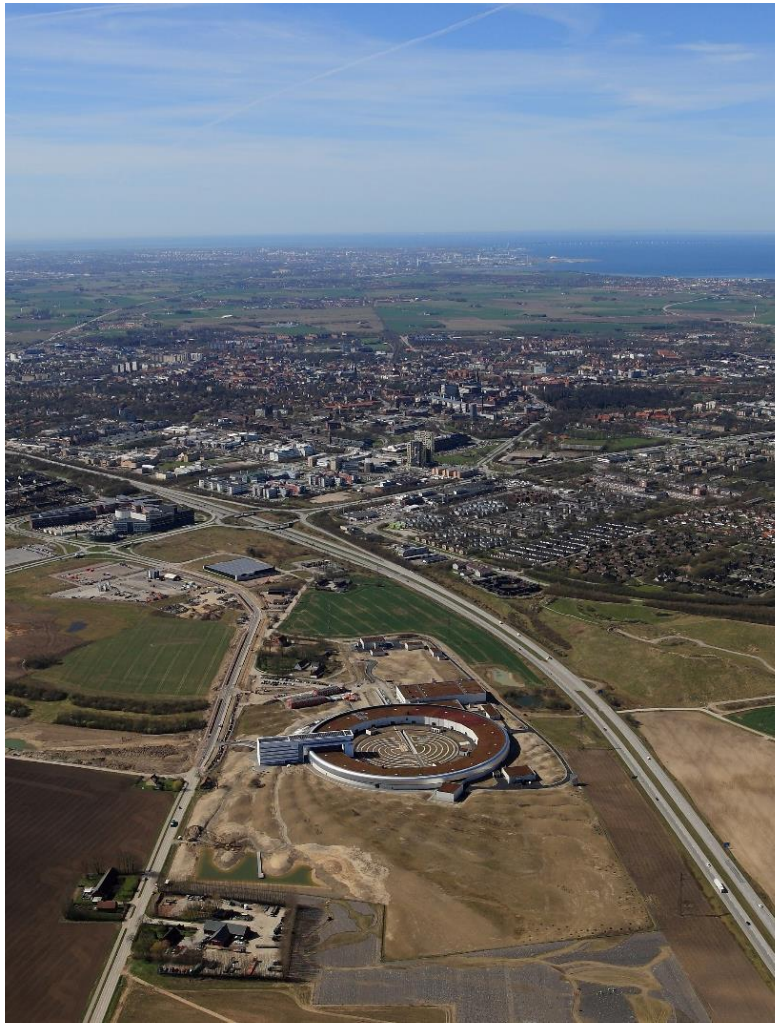
- **Qualitative**
  Describes the different categories of likelihood and consequence in words. Relies on expert judgement and experience rather than precise numerical data.
- **Semi-quantitative**
  Assigns numerical ranges to the qualitative categories of likelihood and consequence. Combines elements of both qualitative and quantitative assessments. Can provide a more structured and objective approach than purely qualitative assessments.



# MAX IV

# MAX IV


MAXPEEM
FinEstBeAMS
Bloch
HIPPIE
SoftiMAX
FemtoMAX
R1
SPECIES
FlexPES
Veritas
R3
NanoMAX
DanMAX
MicroMAX
BioMAX
Balder
CoSAXS
ForMAX
Accelerators
Beamlines in operation
Opportunities for
new beamlines



# MAX IV
Radiation safety risk matrix

# Radiation safety risk matrix (MAX IV)

| Consequence | | | | | | |
|---|---|---|---|---|---|---|
| | High<br>>1 Sv | Low | Moderate | High | High | High |
| | Moderate<br>20 mSv to 1 Sv | Low | Low | Moderate | High | High |
| | Low<br>6 to 20 mSv | Routine | Low | Low | Moderate | Moderate |
| | Routine<br><6 mSv | Routine | Routine | Routine | Routine | Routine |
| | | Extremely remote | Remote | Occasional | Probable | Frequent |
| | | Likelihood | | | | |

# Risk consequence classification (MAX IV)

| Descriptor | Potential consequence (worker) |
|---|---|
| High | >1 Sv |
| Moderate | 20 mSv to 1 Sv |
| Low | 6 to 20 mSv |
| Routine | <6 mSv |

# Risk probability classification (MAX IV)

| Descriptor | Frequency |
|---|---|
| Frequent | Likely to occur repeatedly during the life cycle of the facility |
| Probable | Likely to occur several times during the life cycle of the facility |
| Occasional | Likely to occur sometime during the life cycle of the facility |
| Remote | Unlikely to occur during the life cycle of the facility, but possible |
| Extremely remote | Probability of occurrence is effectively zero |

# Risk category (MAX IV)

| Risk category | |
|---|---|
| High | Unacceptable |
| Moderate | Unacceptable |
| Low | Acceptable |
| Routine | Acceptable |

# Radiation safety assessment (MAX IV)

The risk matrix is used to assess risks related to ionizing radiation by considering the likelihood of occurrence against the potential consequence severity of different events and conditions before and after mitigation. The radiation safety risk assessments include normal and abnormal events inside and outside the accelerators and beamlines.

- **Accelerators**
  One main radiation safety assessment for the accelerators. In addition, separate radiation safety analyses for two test facilities (electron gun test facility, cavity conditioning facility) and a diagnostic accelerator branch. In total 4 accelerator reports.
- **Beamlines**
  One radiation safety assessment per beamline. In total 16 beamline reports.



MAX IV

# MAX IV

Example: Hard x-ray beamline (3 GeV ring)

# Example: R3 hard x-ray beamline (● = risk before mitigation)

| Consequence | Extremely remote | Remote | Occasional | Probable | Frequent |
|---|---|---|---|---|---|
| High >1 Sv | | | ● ● ● | ● | ● |
| Moderate 20 mSv to 1 Sv | ● | ● ● | | ● | ● |
| Low 6 to 20 mSv | | ● | ● | ● | |
| Routine <6 mSv | ● ● | ● ● ● ● ● ● ● | ● ● ● ● ● ● | ● ● ● ● ● ● ● | ● ● ● ● ● ● ● ● ● ● ● ● ● |

Likelihood

# Example: R3 hard x-ray beamline (● = risk before mitigation)

| Consequence | Extremely remote | Remote | Occasional | Probable | Frequent |
|---|---|---|---|---|---|
| High >1 Sv | | | ● ● ● Inside beamline hutch while beam is on | ● | ● |
| Moderate 20 mSv to 1 Sv | ● | ● ● | | ● Exp. hutch chicane removal | ● |
| Low 6 to 20 mSv | | ● | ● | ● | |
| Routine <6 mSv | ● ● | ● ● ● ● ● ● ● | ● ● ● ● ● ● | ● ● ● ● ● ● ● | ● ● ● ● ● ● ● ● ● ● ● ● ● |
| | Likelihood | | | | |

# Risk inside experimental hutch: Individual present after search

**Design mitigation factors**

- Audio and visual information and warnings
- Strategically located search buttons to ensure complete coverage
- Search procedure performed in specified order with time constraints
- Warning period before the beam shutters can be opened
- Emergency stops located within and outside of the hutch
- Only authorised (educated/trained) personnel have access (ID tag system)

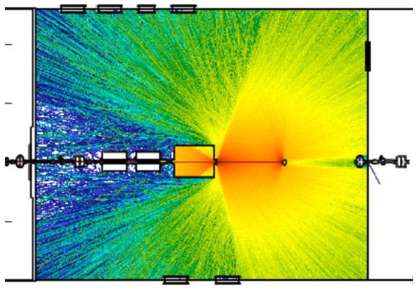
**Operational mitigation factors**

- Active personal dosimeters
- Education/training of personnel

[1] Radiation safety analysis for the MicroMAX beamline. S. Ansell, K. Batkov, A. Rosborg

**Before mitigation**

- Consequence: High
- Likelihood: Frequent



*Example from [1]*

**After mitigation**

- Consequence: High
- Likelihood: Extremely remote

# Risk inside experimental hutch: PSS hardware failure

**Design mitigation factors**

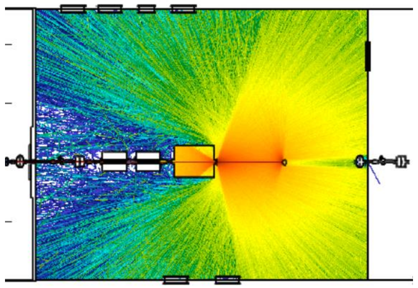
- Safety rated PLC based PSS
- Safety rated PSS components
- PSS online error detection
- Audio and visual information and warnings
- Emergency stops located within and outside of the hutch

**Operational mitigation factors**

- Active personal dosimeters
- Education/training of personnel
- All work on PSS reviewed and approved by radiation safety team
- Periodic testing of PSS

**Before mitigation**

- Consequence: High
- Likelihood: Occasional



*Example from [1]*

**After mitigation**

- Consequence: High
- Likelihood: Extremely remote



MAX IV

# Risk outside experimental hutch: Chicane removal (both sides)

**Design mitigation factors**

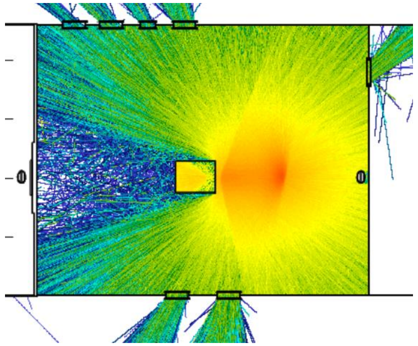
- Paint chicanes in an easily recognizable color (orange)
- Label chicanes to inform that removal is prohibited without prior approval from the radiation safety team
- Replace some of the screws/nuts used to fasten the chicane by screws/nuts which require a special handle to un-tighten

**Operational mitigation factors**

- Education/training of personnel to inform that chicane removal is prohibited without prior approval from the radiation safety team
- Radiological work permit required before chicane is opened
- Periodic inspection of chicanes

**Before mitigation**

- Consequence: Moderate
- Likelihood: Probable



*Example from [1]*

**After mitigation**

- Consequence: Moderate
- Likelihood: Extremely remote

# Example: R3 hard x-ray beamline (○ = risk after mitigation)

| Consequence | | | | | |
|---|---|---|---|---|---|
| High >1 Sv | ○ ○ | | | | |
| Moderate 20 mSv to 1 Sv | ○ ○ ○ ○ ○ | | | | |
| Low 6 to 20 mSv | | | | | |
| Routine <6 mSv | ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ | ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ ○ | | ○ | ○ ○ ○ ○ ○ ○ ○ ○ ○ |
| | Extremely remote | Remote | Occasional | Probable | Frequent |
| | Likelihood | | | | |

# MAX IV

Example: Soft x-ray beamline (1.5 GeV ring)

# Example: R1 soft x-ray beamline (● = risk before mitigation)

| Consequence | | | | | | |
|---|---|---|---|---|---|---|
| | High<br>>1 Sv | | | | | |
| | Moderate<br>20 mSv to 1 Sv | | ● | | | |
| | Low<br>6 to 20 mSv | | | | | |
| | Routine<br><6 mSv | ●● | ●●●●●● | ●●●●●●●● | ●●●●●●● | ●●●●●●●●● |
| | | Extremely remote | Remote | Occasional | Probable | Frequent |
| | | Likelihood | | | | |

# Example: R1 soft x-ray beamline (● = risk before mitigation)

| Consequence | | | | | | |
|---|---|---|---|---|---|---|
| Consequence | High<br>>1 Sv | | | | | |
| Consequence | Moderate<br>20 mSv to 1 Sv | | ● Top-up | | | |
| Consequence | Low<br>6 to 20 mSv | | | | | |
| Consequence | Routine<br><6 mSv | ●● | ●●●●●● | ●●●●●●●● | ●●●●●●● | ●●●●●●●●● |
| | | Extremely remote | Remote | Occasional | Probable | Frequent |
| | | Likelihood | | | | |

# Risk outside optics hutch: Top-up, injected beam in front-end

**Design mitigation factors**

- Monitoring the stored current
- Monitoring the ring dipoles
- Front-end permanent magnet
- Online radiation monitor system
- Charge budget

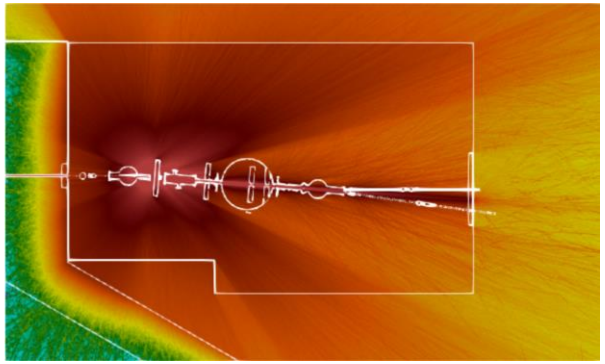
**Operational mitigation factors**

- Periodic inspection of permanent magnet

[2] Radiation safety analysis for the SPECIES beamline. S. Ansell, M. Hörling, J. Malmqvist, J. Paulson, J. Reftlér, A. Rosborg

**Before mitigation**

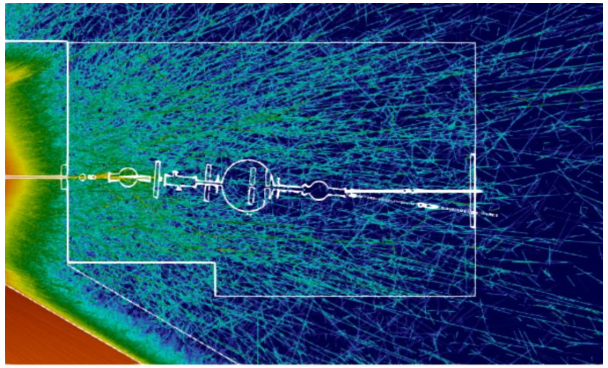
- Consequence: Moderate
- Likelihood: Remote



*No permanent magnet (example from [2])*

**After mitigation**

- Consequence: Routine
- Likelihood: Remote



*With permanent magnet (example from [2])*

# Example: R1 soft x-ray beamline (○ = risk after mitigation)

| Consequence | | | | | |
|---|---|---|---|---|---|
| High<br>>1 Sv | | | | | |
| Moderate<br>20 mSv to 1 Sv | | | | | |
| Low<br>6 to 20 mSv | | | | | |
| Routine<br><6 mSv | ○ ○ ○ ○ ○ ○ ○<br>○ ○ ○ ○ ○ | ○ ○ ○ ○ ○ ○ ○<br>○ ○ ○ ○ ○ ○ | | ○ | ○ ○ ○ ○ ○ ○ ○ |
| | Extremely remote | Remote | Occasional | Probable | Frequent |
| | Likelihood | | | | |

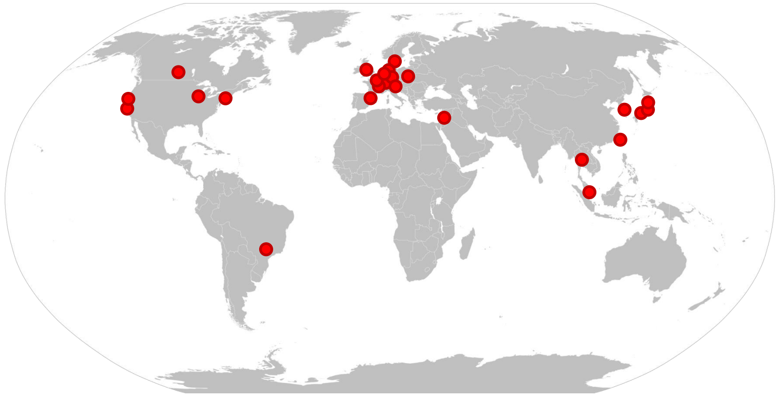
# Other synchrotron light sources

# Survey

Two questions were sent to the 25 facilities that attended RadSynch19 and/or RadSynch23.

- *Do you use a risk matrix to assess the radiation safety risks by considering the likelihood and potential severity of different events and conditions? If not, have you used some other method to assess the risks, e.g. a hazard analysis or a quantitative method?*
- *Have you, e.g. in a risk assessment or when designing the PSS, assigned a likelihood to the event that a person is exposed to ionizing radiation inside an accelerator area or beamline hutch while beam is on? For example, due to failure of a safety shutter or failure of a search. If yes, was it a qualitatively assigned likelihood or a calculated probability from e.g. a fault tree analysis or event tree analysis?*

**Many thanks to all who responded!**



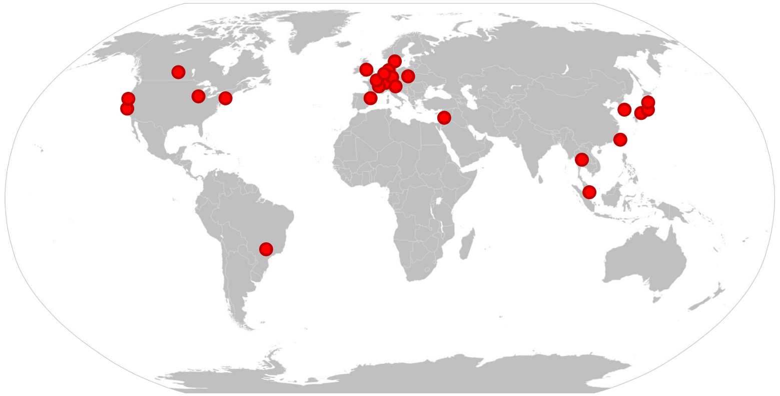
# Survey

Many thanks to all who responded! I hope that your responses have been correctly represented in the following slides. Apologies if there are any errors or misunderstandings.

The focus of this part of the presentation is on the facilities that responded that they use a risk matrix to assess risks related to ionizing radiation.

Using a risk matrix is just one possible risk management tool. Examples of other tools used at the facilities is hazard analyses or failure mode and event analyses, where possible scenarios and countermeasures are identified.

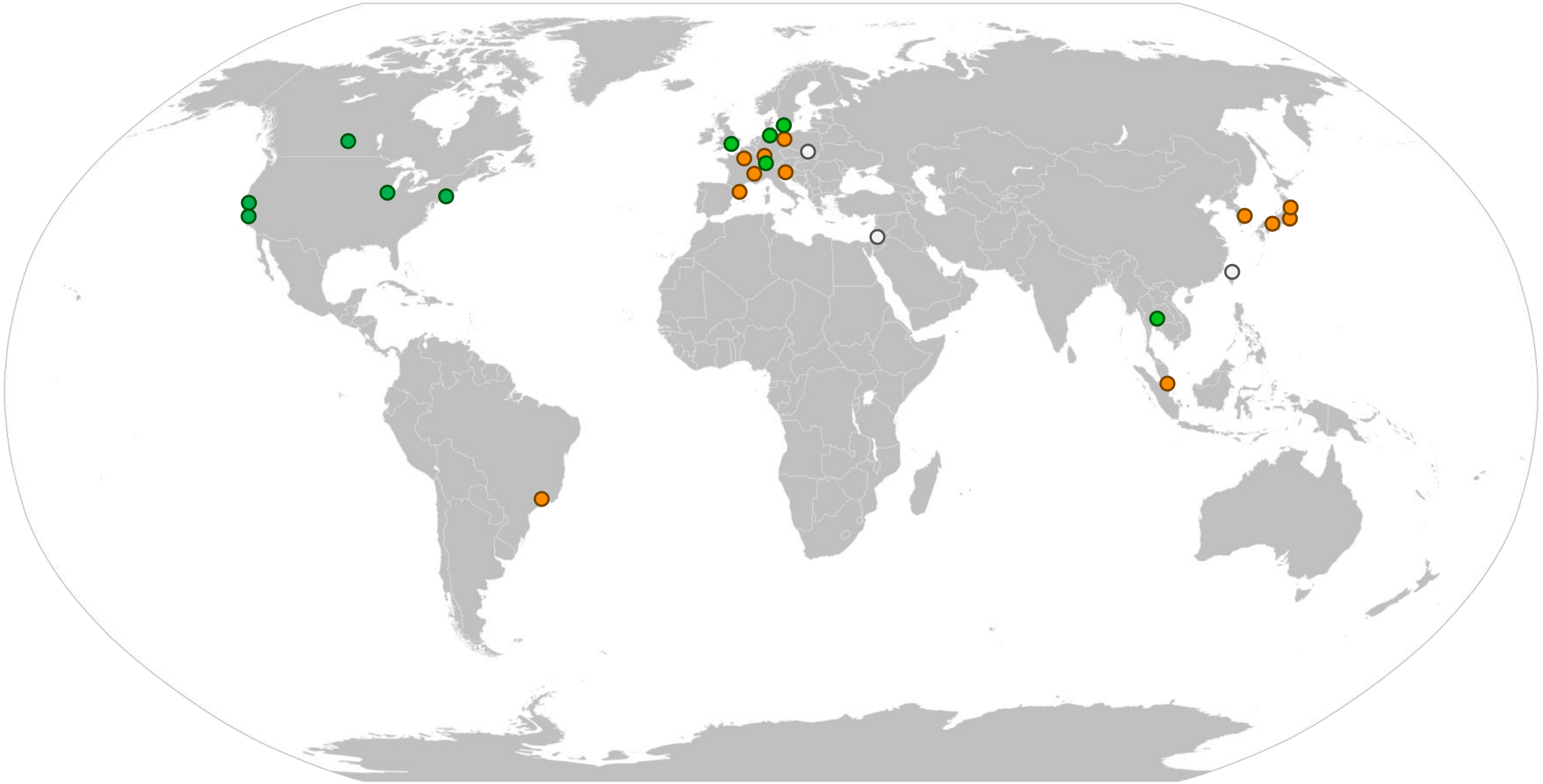
A common theme in the responses is the use of interlock systems and operational procedures to minimize the risk. For the interlock systems, the use of suitable safety rated components and requirements on the performance level and/or safety integrity level of the safety functions is mentioned.



# Other synchrotron light sources

Overview

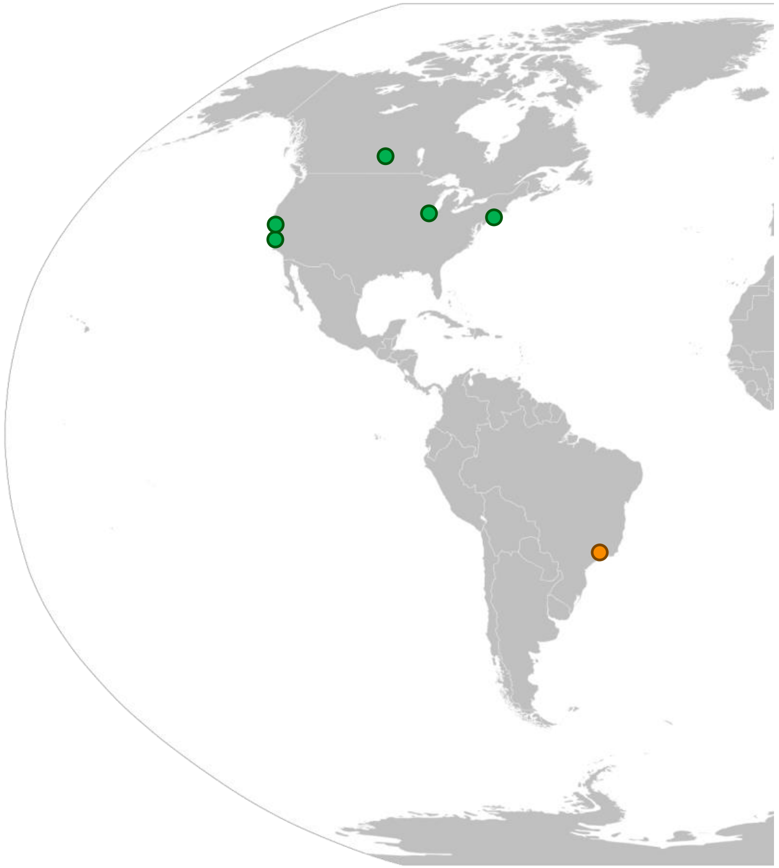
# Use of risk matrix to assess risks related to ionizing radiation?



- = Yes
- = No
- = No response

# Americas

| Facility | Country | Radiation safety risk matrix? |
|---|---|---|
| CLS | Canada | Yes |
| NSLS-II | USA | Yes |
| APS | USA | Yes |
| ALS | USA | Yes |
| SLAC | USA | Yes |
| Sirius | Brazil | No |

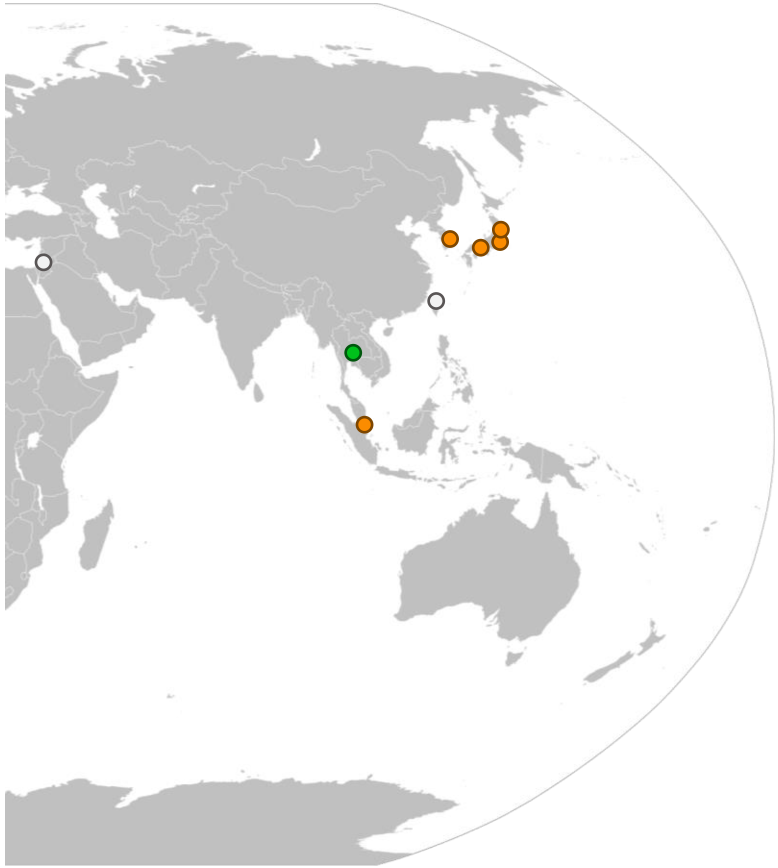


# Europe

| Facility | Country | Radiation safety risk matrix? |
|---|---|---|
| MAX IV | Sweden | Yes |
| DESY, European XFEL | Germany | Yes |
| BESSY | Germany | No |
| KIT | Germany | No |
| Diamond | UK | Yes |
| SOLARIS | Poland | ? |
| PSI | Switzerland | Yes |
| Synchrotron SOLEIL | France | No |
| ESRF | France | No |
| Elettra | Italy | No (?) |
| ALBA | Spain | No |

# Asia

| Facility | Country | Radiation safety risk matrix? |
|---|---|---|
| SESAME | Jordan | ? |
| PAL | South Korea | No |
| NanoTerasu | Japan | No |
| KEK | Japan | No |
| SPring-8 | Japan | No |
| NSRRC | Taiwan | ? |
| SSLS | Singapore | No |
| SLRI | Thailand | Yes (?) |



# Other synchrotron light sources
## NSLS-II

*Thanks to Ricardo dos Santos Augusto at NSLS-II for sharing this information*

# Risk matrix (NSLS-II)

| Consequence | | | | | | | |
|---|---|---|---|---|---|---|---|
| Consequence | High >1 Sv | Routine | Low | Moderate | High | High | High |
| | Moderate >250 mSv | Routine | Low | Low | Moderate | High | High |
| | Low >50 mSv | Routine | Routine | Low | Low | Moderate | Moderate |
| | Routine <20 mSv | Routine | Routine | Routine | Routine | Routine | Routine |
| | | Impossible | Extremely remote | Remote | Occasional | Probable | Frequent |
| | | Probability | | | | | |

# Risk consequence classification (NSLS-II)

| Descriptor | Potential consequence (excerpt) |
|---|---|
| High | Can a radiological or chemical hazard cause multiple deaths or serious injury, [...], >100 rem to an individual, [...] |
| Moderate | Can a radiological or chemical hazard cause a death or serious injury, >25 rem to an individual, [...] |
| Low | Can a radiological or chemical hazard cause multiple moderate injuries, [...], >5 rem to an individual, [...] |
| Routine | Can a radiological or chemical hazard cause minor injuries, [...], <2 rem to an individual, [...] |

# Risk probability classification (NSLS-II)

| Descriptor | Frequency |
|---|---|
| Frequent | Likely to occur repeatedly during the life cycle of the system |
| Probable | Likely to occur several times in the life cycle of the system |
| Occasional | Likely to occur sometime in the life cycle of the system |
| Remote | Unlikely to occur in the life cycle of the system, but possible |
| Extremely remote | Probability of occurrence ~zero |
| Impossible | Physically impossible to occur |

# Risk category (NSLS-II)

| Risk category | |
|---|---|
| High | Unacceptable |
| Moderate | Unacceptable |
| Low | Acceptable |
| Routine | Acceptable |

# Exposure within an accelerator or beamline enclosure (NSLS-II)

**Mitigation factors (Design of PPS level interlocks)**

- Redundant and independent interlock systems to minimize risk of unsafe failure
- Design of interlocks to requirements of ANSI/ISA-84.00.01-2004
- Design review by experts independent of NSLS-II project
- Failure mode analysis of interlock design to identify potential vulnerabilities of proposed interlock design
- Provisions of audible and visual warnings of search and secure within an enclosure
- Provision of emergency off buttons within an enclosure providing means of preventing the introduction of beam to an enclosure

**Prior to mitigation**

- Consequence: High
- Probability: Occasional

**Following mitigation**

- Consequence: High
- Probability: Extremely remote

# Exposure within an accelerator or beamline enclosure (NSLS-II)

**Mitigation factors (Operational)**

- All work on PPS level interlocks reviewed and approved by independent safety officer
- All design changes or new systems must be reviewed by independent group of qualified personnel
- Only trained and authorized workers allowed access to PPS interlocks for maintenance or modification
- All PPS interlocks must be tested and certified at interval required by SBMS/RadCon Manual and following any modification
- Search and secure performed only by trained and qualified personnel
- All personnel accessing an enclosure trained to recognize warning signals and emergency off locations

**Prior to mitigation**

- Consequence: High
- Probability: Occasional

**Following mitigation**

- Consequence: High
- Probability: Extremely remote

# Other synchrotron light sources

APS

*Thanks to Sunil Chitra at APS for sharing this information*

MAX IV

# Risk ranking matrix (APS)

| Consequence | | | | | |
|---|---|---|---|---|---|
| Consequence | High<br>>250 mSv | Acceptable | Marginal | Unacceptable | Unacceptable |
| | Moderate<br>50 to 250 mSv | Negligible | Acceptable | Marginal | Marginal |
| | Low<br>5 to 50 mSv | Negligible | Negligible | Acceptable | Acceptable |
| | Negligible<br><5 mSv | Negligible | Negligible | Negligible | Negligible |
| | | Beyond extremely unlikely<br>$<10^{-6}$ | Extremely unlikely<br>$10^{-4}$ to $10^{-6}$ | Unlikely<br>$10^{-2}$ to $10^{-4}$ | Anticipated<br>$>10^{-2}$ |
| | | Frequency | | | |

# Consequence bin designations (APS)

| Bin | Facility worker consequence |
|---|---|
| High | Radiological: Total effective dose >25 rem<br>Other Hazards: Loss of life or serious injury that requires extensive professional medical attention |
| Moderate | Radiological: Total effective dose between 5 and 25 rem<br>Other Hazards: Moderate (but not life threatening) injuries that require professional medical attention |
| Low | Radiological: Total effective dose between 0.5 and 5 rem<br>Other Hazards: Minor injuries that require only superficial medical attention |
| Negligible | Negligible or no measurable impact |

# Frequency bin designations (APS)

| Bin | Description | Likelihood range (/year) |
|---|---|---|
| Anticipated | Events that may occur several times during the lifetime of the facility | More than once/yr to once/100 yrs |
| Unlikely | Events that are not anticipated to occur (but could potentially occur) during the lifetime of the facility | once/100 yrs to once/10,000 yrs |
| Extremely unlikely | Events that will probably not occur during the lifetime of the facility | once/10,000 yrs to once/1,000,000 yrs |
| Beyond extremely unlikely | Events whose probability of occurrence is so small that it is not considered reasonable | less often than once/1,000,000 yrs |

# Risk ranking bins (APS)

| Risk rank | Control selection guideline |
|---|---|
| 1 | Unacceptable Risk (Major Concern) – Controls are required to prevent (reduce frequency) or mitigate (reduce consequence) as necessary to achieve a risk rank of 3 or 4. |
| 2 | Marginal Risk (Marginal Concern) – Controls must be considered to prevent or mitigate as necessary to achieve a risk rank of 3 or 4. Controls for unique hazards that are not adequately covered by SMPs should be elevated to ASE-level controls. |
| 3 | Acceptable Risk (Minor Concern) – Generally protected by Safety Manangement Programs. However, controls for unique hazards that are not adequately covered by SMPs should be considered for ASE-level controls. |
| 4 | Negligible Risk (Minimal Concern) – Managed by Safety Management Programs (additional controls are not required) |

# Personnel exposed to radiation inside accelerator tunnel (APS)

**Engineered preventive features**

- ACIS – Access control feature (credited)

**Administrative preventive features**

- ACIS storage ring tunnel search
- Radiological protection program
- Conduct of operations program (procedures, training, work control)

**Initial risk evaluation**

- Consequence:
  High
- Probability:
  Anticipated

**Residual risk evaluation**

- Consequence:
  High
- Probability:
  Beyond extremely unlikely

# Personnel inside beamline station while x-ray beam is on (APS)

**Engineered preventive features**

- PSS – Access control feature and emergency shutdown buttons
- ACIS – Shutters
- Radiation shielding (credited)

**Administrative preventive features**

- Search and secure procedure
- Radiological protection program
- Conduct of operations program (procedures, training, work control)

**Initial risk evaluation**

- Consequence: High
- Probability: Anticipated

**Residual risk evaluation**

- Consequence: High
- Probability: Beyond extremely unlikely

# Other synchrotron light sources

ALS & ALS-U

*Thanks to Stefania Trovati at ALS for sharing this information*

MAX IV

# Hazard analysis risk matrix (ALS)

| Consequence | | | | | |
|---|---|---|---|---|---|
| Consequence | A. death/loss of facility >1 Sv | Low | Moderate | High | High |
| | B. severe injury 250 mSv - 1 Sv | Negligible | Low | Moderate | High |
| | C. minor injury 50 to 250 mSv | Negligible | Negligible | Low | Low |
| | D. negligible <50 mSv | Negligible | Negligible | Negligible | Negligible |
| | | Extremely Low $<10^{-4}$ | Low $10^{-2}$ to $10^{-4}$ | Medium $10^{-1}$ to $10^{-2}$ | High $>10^{-1}$ |
| | | Frequency | | | |

# Hazard analysis risk matrix (ALS-U)

| Consequence | | | | | |
|---|---|---|---|---|---|
| Consequence | A. death/loss of facility >1 Sv | Low | Moderate | High | High |
| | B. severe injury 250 mSv - 1 Sv | Negligible | Low | Moderate | High |
| | C. minor injury 50 to 250 mSv | Negligible | Low | Low | Moderate |
| | D. negligible <50 mSv | Negligible | Negligible | Negligible | Low |
| | | Extremely Low $<10^{-4}$ | Low $10^{-2}$ to $10^{-4}$ | Medium $10^{-2}$ to $10^{-1}$ | High $>10^{-1}$ |
| | | Frequency | | | |

# Consequences of occurrence (ALS)

| Level | Consequence Description (worker) [excerpt] |
|---|---|
| A | Potential for immediate and severe health effects, significant long-term health effects or diability, or potential loss of life. Very large radioactive material dispersal (qualitative dose estimate >100 rem) […] |
| B | Serious injury or significant radiation or chemical exposure. Significant radioactive material dispersal (between 25 and 100 rem) […] |
| C | Minor injuries with no disability or work restrictions. Low energy and/or small radioactive release yielding minor dispersion (<25 rem) […] |
| D | Negligible impact |

# Probability rating levels (ALS)

| Category | Description | Estimated range of probability of accident per year |
|---|---|---|
| High | Event is likely to occur several times during the facility of operation lifetime | $>10^{-1}$ |
| Medium | Event anticipated to occur on-ce or twice during the facilities lifetime (such as 100-yr flood) | $10^{-1}$ to $10^{-2}$ |
| Low | Event should not occur during the facility's lifetime (such as a design basis event) | $10^{-2}$ to $10^{-4}$ |
| Extremely low | Probability of event is incredible | $<10^{-4}$ |

# Other synchrotron light sources

## SLAC

*Thanks to S. Rokni, S. Xiao, and J. Bauer at SLAC for sharing this information*

MAX IV

# Risk matrix (SLAC)

| Consequence | | | | | |
|---|---|---|---|---|---|
| | High | Low | Medium | High | High |
| | Medium | Extremely Low | Low | Medium | High |
| | Low | Extremely Low | Extremely Low | Low | Medium |
| | Extremely low | Extremely Low | Extremely Low | Extremely Low | Low |
| | | Extremely Low | Low | Medium | High |
| | | Probability | | | |

# Hazard consequence rating levels (SLAC)

| Consequence level | Maximum consequence |
|---|---|
| High | Serious impact on-site or off-site. May cause deaths or loss of the facility/operation. Major impact on the environment. Significant regulatory or contractual violation. Possible national negative publicity. |
| Medium | Major impact on-site or off-site. May cause severe injuries or severe occupa-tional illness to personnel or major damage to a facility or moderate impact on the environment. Capable of returning to operation. May result in regulatory or contractual violation. Possible local or statewide negative publicity. |
| Low | Minor on-site with negligible off-site impact. May cause minor injury or minor occupational illness or minor impact on the environment. De minimis regulatory or contractual violation. Likely no negative publicity. |
| Extremely low | Will not result in a significant injury or occupation illness or provide a significant impact on the environment. |

# Hazard probability of occurrence levels (SLAC)

| Category | Description |
|---|---|
| High | Event is likely to occur several times in a year |
| Medium | Event is likely to occur annually |
| Low | Event is likely to occur during the life of the facility or operation |
| Extremely low | Occurrence is unlikely or the event is not expected to occur during the life of the facility or operation |
| Incredible | Probability of occurrence is so small that a reasonable scenario is inconceivable. These events are not analyzed further. |



MAX IV

# Risk level (SLAC)

| Risk level | |
|---|---|
| High | Unacceptable |
| Medium | Unacceptable |
| Low | Acceptable |
| Extremely low | Acceptable |

# Prompt ionizing radiation inside accelerator enclosure (SLAC)

**Mitigating factors and assumptions (Design)**

- Engineered Personnel Protection Systems (PPS) to control access to accelerator housing and turn off accelerator when barriers are violated.

**Mitigating factors and assumptions (Operational)**

- Ongoing maintenance and certification of PPS per SLAC standards
- Radiation safety training for all personnel who may access accelerator housings
- Additional access control processes including search procedures, interlock checklists, entry/exit procedures, formal operator qualifications on PPS systems
- See also the Accelerator Safety Envelope (ASE) document

**Prior to mitigation**

- Consequence: High
- Probability: High

**Following mitigation**

- Consequence: High
- Probability: Extremely low

# Other synchrotron light sources

Diamond

*Thanks to Sanjeev Faruk at Diamond for sharing this information*

# Risk rating matrix (Diamond)

| Severity | | | | | | |
|---|---|---|---|---|---|---|
| | 5. Death | 5 | 10 | 15 | 20 | 25 |
| | 4. Major injury | 4 | 8 | 12 | 16 | 20 |
| | 3. Moderate ef. | 3 | 6 | 9 | 12 | 15 |
| | 2. Minor effect | 2 | 4 | 6 | 8 | 10 |
| | 1. Trivial effect | 1 | 2 | 3 | 4 | 5 |
| | | 1. Improbable | 2. Unlikely | 3. Occasional | 4. Frequently | 5. Regular |
| | | Likelihood | | | | |

# Severity (Diamond)

| S | Severity |
|---|---|
| 5 | Death of one or more persons |
| 4 | Major injury, more than seven days off work or HSE reportable (RIDDOR) |
| 3 | Moderate effect, up to seven days of work |
| 2 | Minor effect, lost time, medical attention and rest of the day off work |
| 1 | Trivial effect, first aid may be required, but no lost time away from work |

# Likelihood (Diamond)

| L | Frequency |
|---|---|
| 5 | Regular |
| 4 | Frequently |
| 3 | Occasional |
| 2 | Unlikely |
| 1 | Improbable |

# Risk rating = L x S (Diamond)

| Value (L x S) | Risk rating | Action needed | Review period |
|---|---|---|---|
| ≤6 | Green (Low) | Only if action is cost effective.<br><br>Within 6 months | 36 months |
| >6 ≤12 | Amber (Medium) | Within 3 months | 24 months |
| >12 | Red (High) | Immediately | 6 months |

# Other synchrotron light sources
## PSI

*Thanks to Christine Harm at PSI for sharing this information*

# Risk matrix (PSI) *[Note: Translated from German]*

| Severity | | | | | | |
|---|---|---|---|---|---|---|
| Severity | 1. Death | Medium | Medium | Major | Major | Major |
| | 2. Severe permanent | Minor | Medium | Major | Major | Major |
| | 3. Slight permanent | Minor | Medium | Medium | Major | Major |
| | 4. Curable injury | Minor | Minor | Medium | Medium | Major |
| | 5. Minor case | Minor | Minor | Minor | Medium | Medium |
| | | E. Improbable | D. Very rare | C. Rare | B. Occasional | A. Frequent |
| | | Probability | | | | |

# Schadenausmass / Severity (PSI)

| | Original German | English rough translation |
|---|---|---|
| 1 | Tod | Death |
| 2 | Schwerer, bleibender Gesundheitsschaden | Severe, permanent health damage |
| 3 | Leichter, bleibender Gesundheitsschaden | Slight, permanent health damage |
| 4 | Heilbare Verletzung mit Arbeitsausfall | Curable injury with loss of work |
| 5 | Bagatellfall, leichte Verletzung ohne Arbeitsausfall | Minor case, minor injury without loss of work |

# Wahrscheinlichkeit / Probability (PSI)

| | Original German | English rough translation |
|---|---|---|
| A | Häufig | Frequent |
| B | Gelegentlich | Occational |
| C | Selten | Rare |
| D | Seht selten | Very rare |
| E | Unwahtscheinlich | Improbable |

# Risikozonen / Risk zones (PSI)

| | Original German | English rough translation |
|---|---|---|
| | Grosse Risiken<br>Massnahmen mit erhöhter Schutzwirkung dringend notwendig | Major risks<br>Measures with increased protective effect urgently necessary |
| | Mittlere Risiken<br>Massnahmen mit normaler Schutzwirkung notwendig | Medium risks<br>Measures with normal protective effect necessary |
| | Kleine Risiken<br>Massnahmen technisch, organisatorisch oder personenbezogen | Minor risks<br>Technical, organizational, or personal measures |

# Looking ahead

# New radiation safety risk matrix?

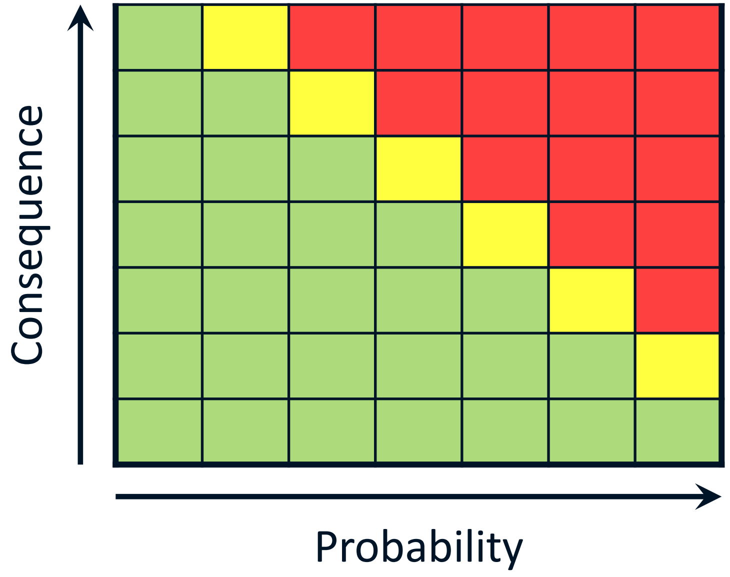
At MAX IV, we are considering adapting a new radiation safety risk matrix. If we do, the following is on our to-do list:

- **Semi-quantitative for both consequence and probability**
  Review the categories for consequence and probability. Change to semi-quantitative probability categories with numerical ranges for probability per year.
- **Risk ranking**
  Review the risk categories. Change to one unacceptable, one acceptable, and one to two intermediate (ALARP) categories?

| | Today |
|---|---|
| (red) | Unacceptable |
| (orange) | Unacceptable |
| (yellow) | Acceptable |
| (green) | Acceptable |

| | New? |
|---|---|
| (red) | Unacceptable |
| (orange) | Undesirable |
| (yellow) | Tolerable |
| (green) | Acceptable |

| | New? |
|---|---|
| (red) | Unacceptable |
| (yellow) | Tolerable |
| (green) | Acceptable |



MAX IV