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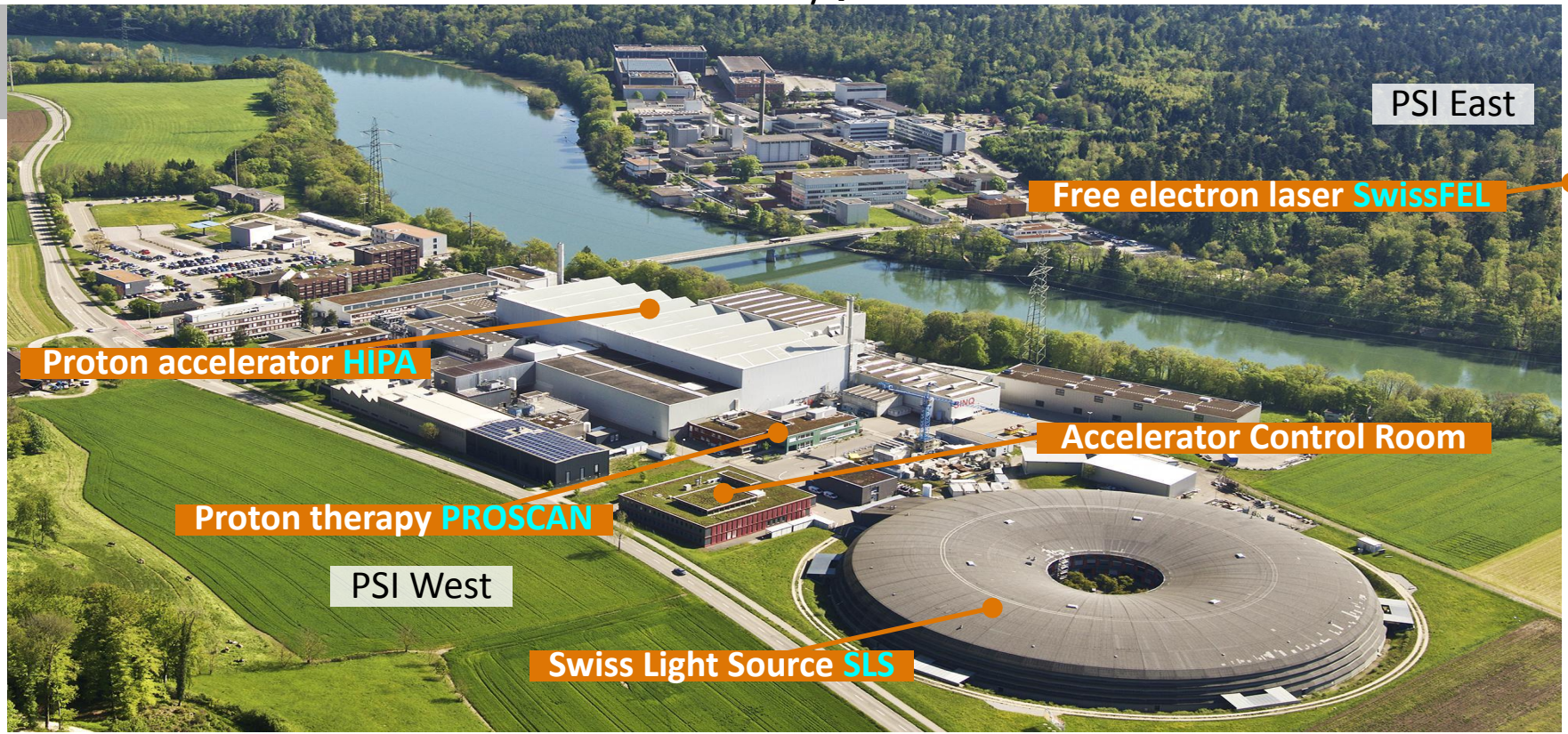
Presented by Felix Armborst on behalf of the SLS 2.0 project team

The Beam Abort System for the SLS 2.0

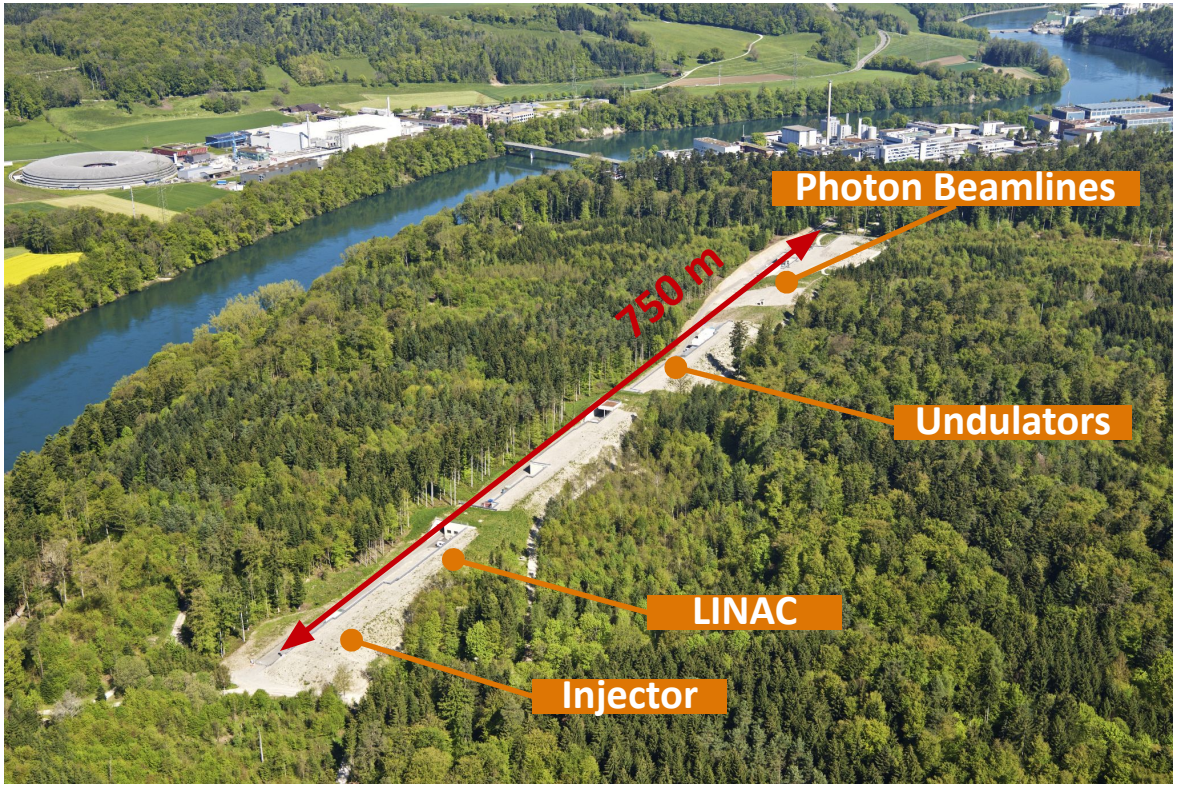
21.10.2022, Accelerator Reliability Workshop, Newport News

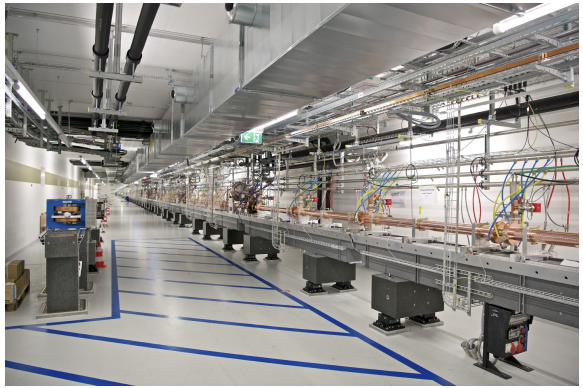
Outline

Accelerator Facilities at the Paul Scherrer Institute

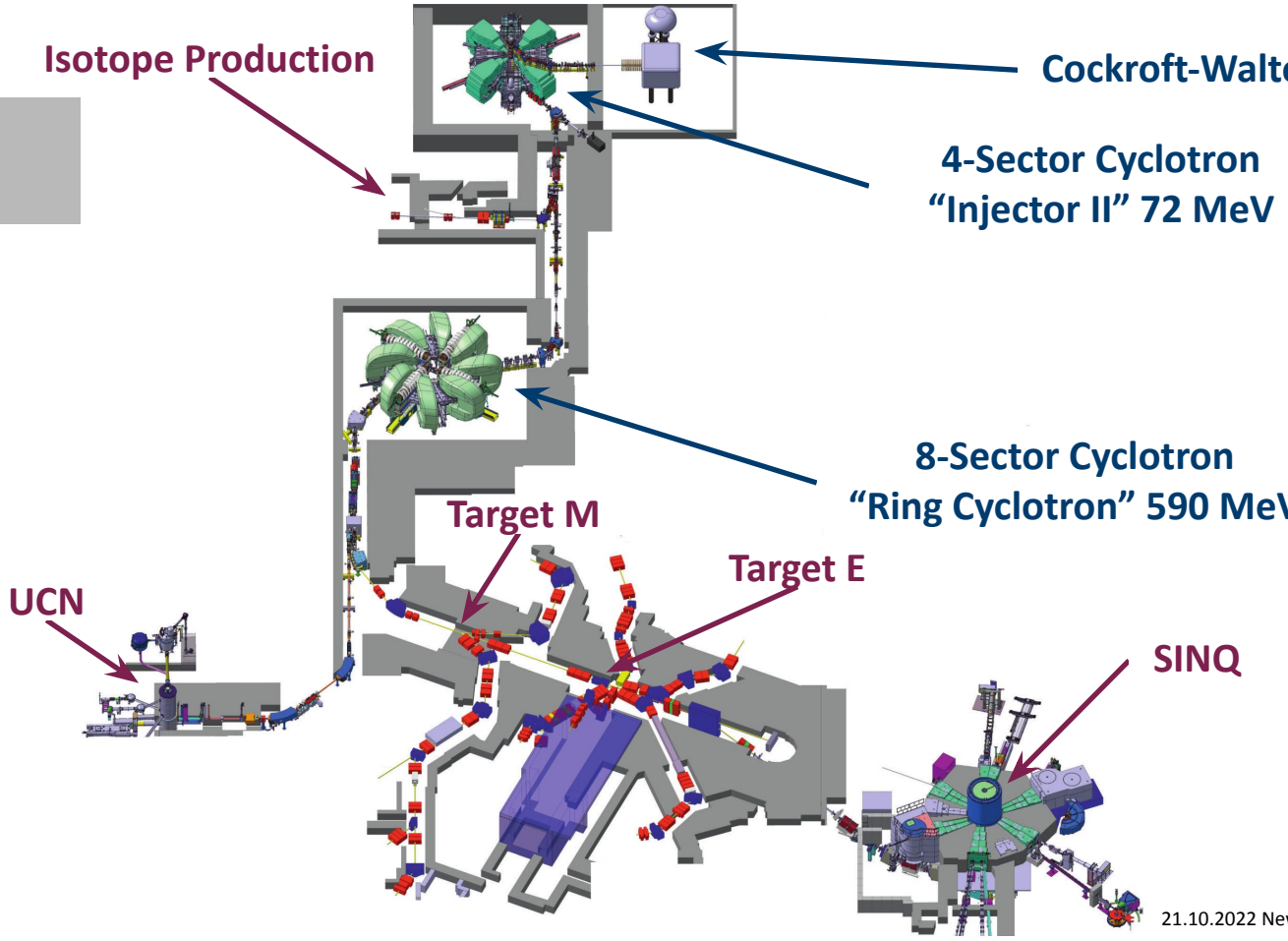


Swiss Free Electron Laser SwissFEL





High Intensity Proton Accelerator HIPA



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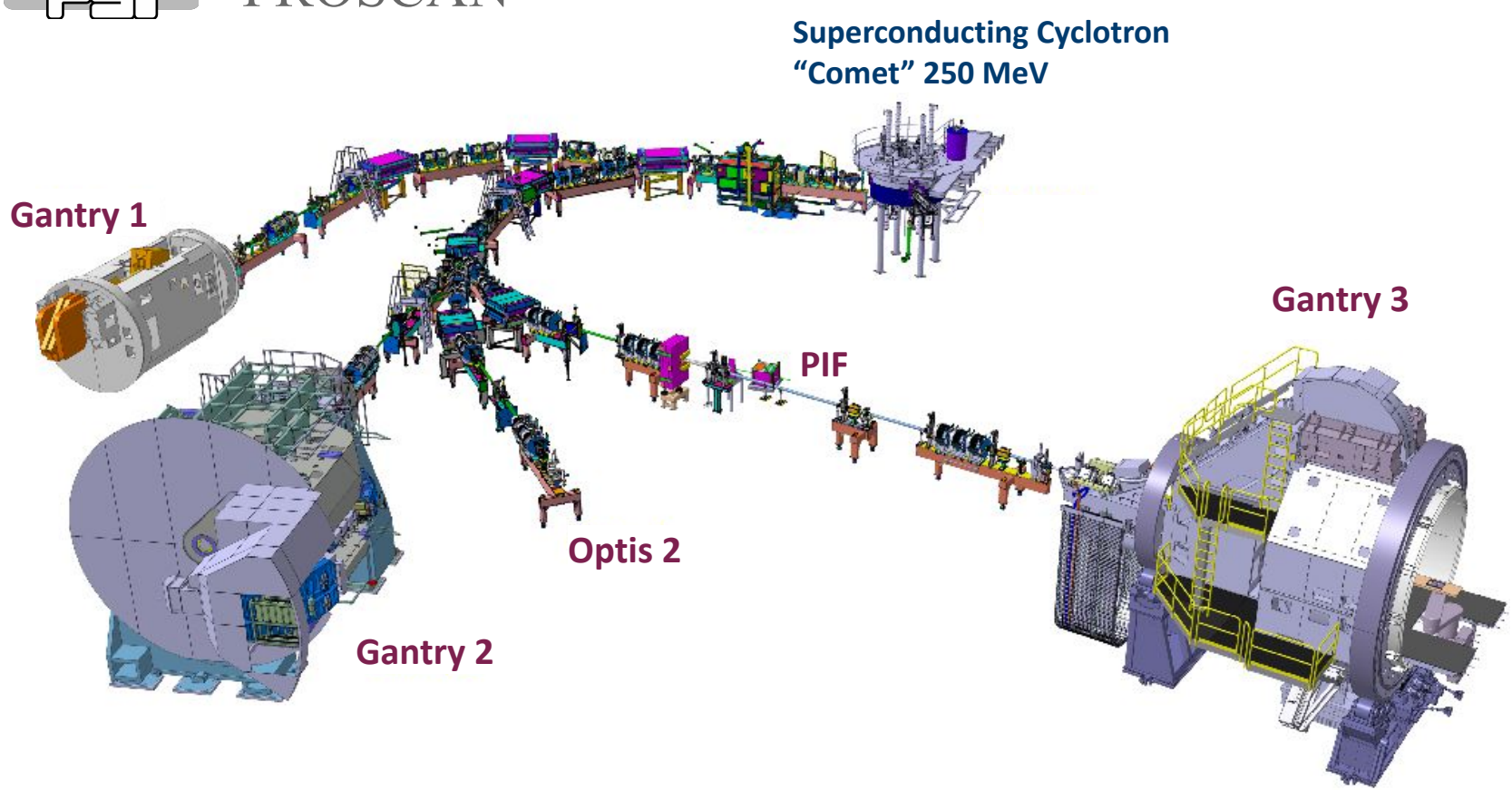
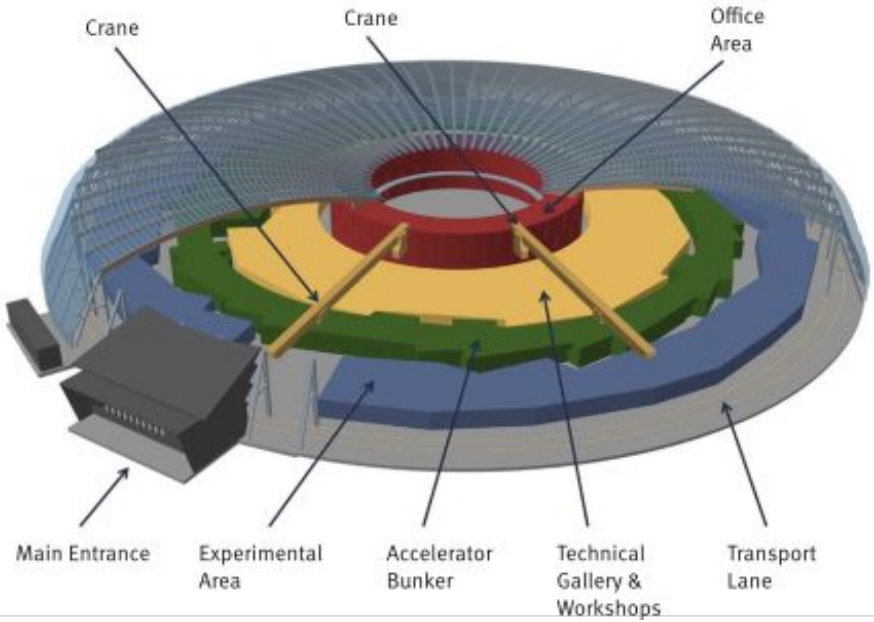
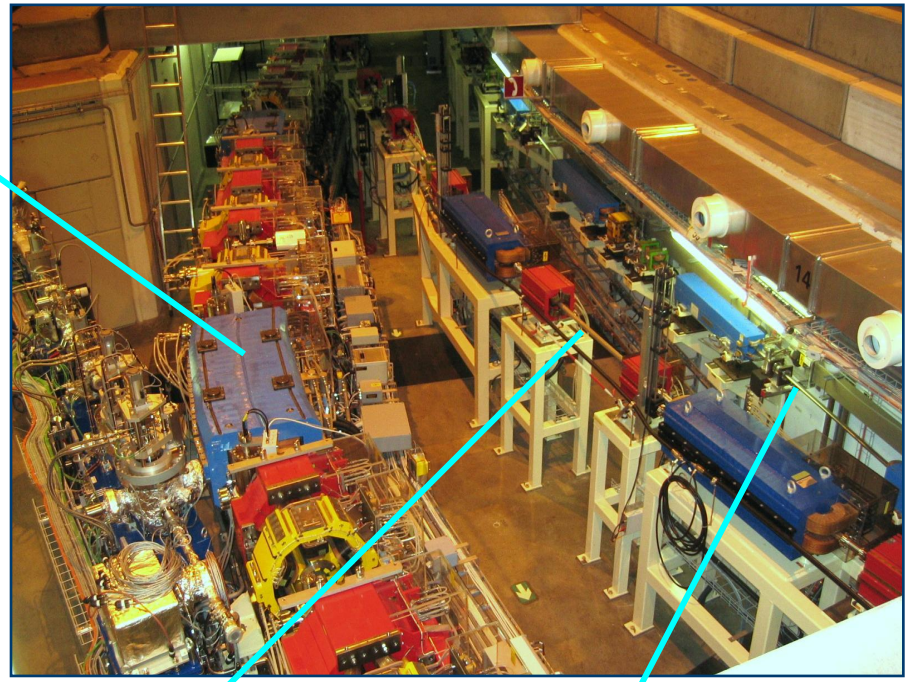


Swiss Light Source - **SLS**





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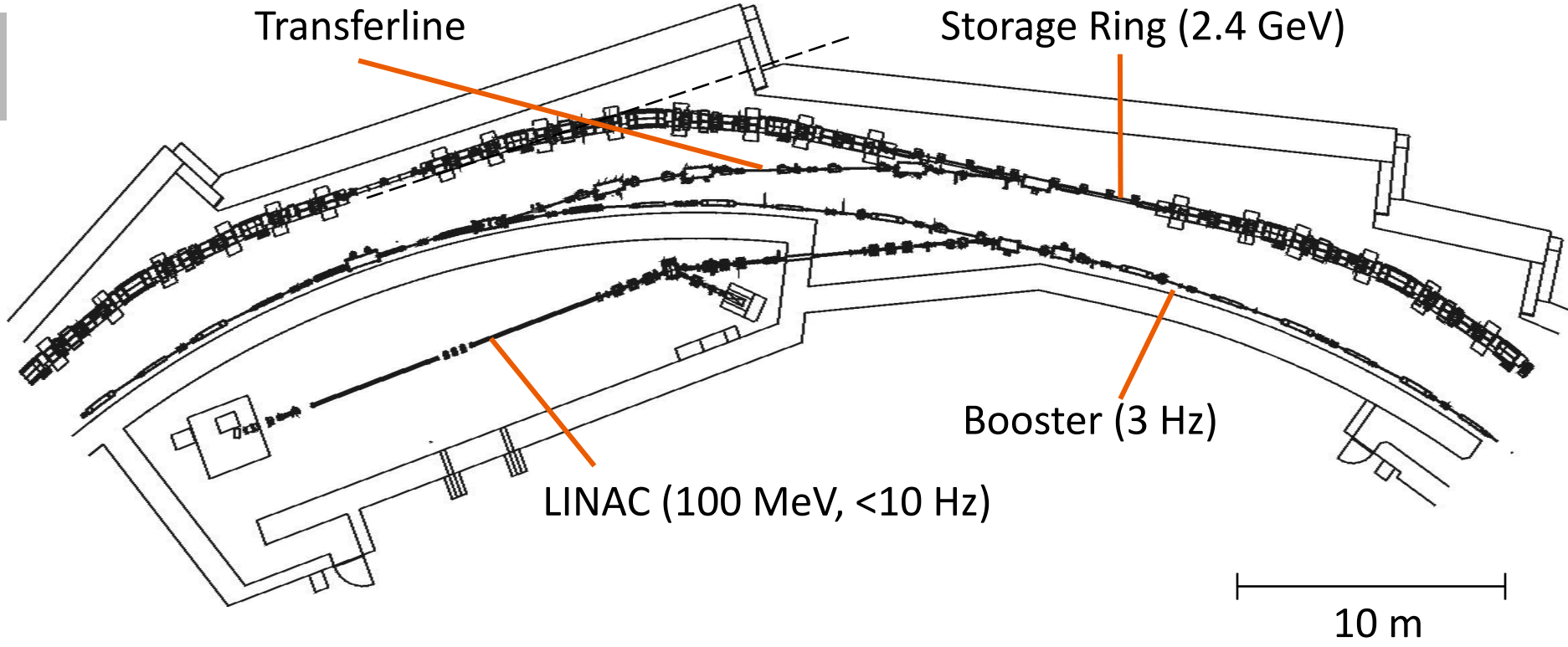
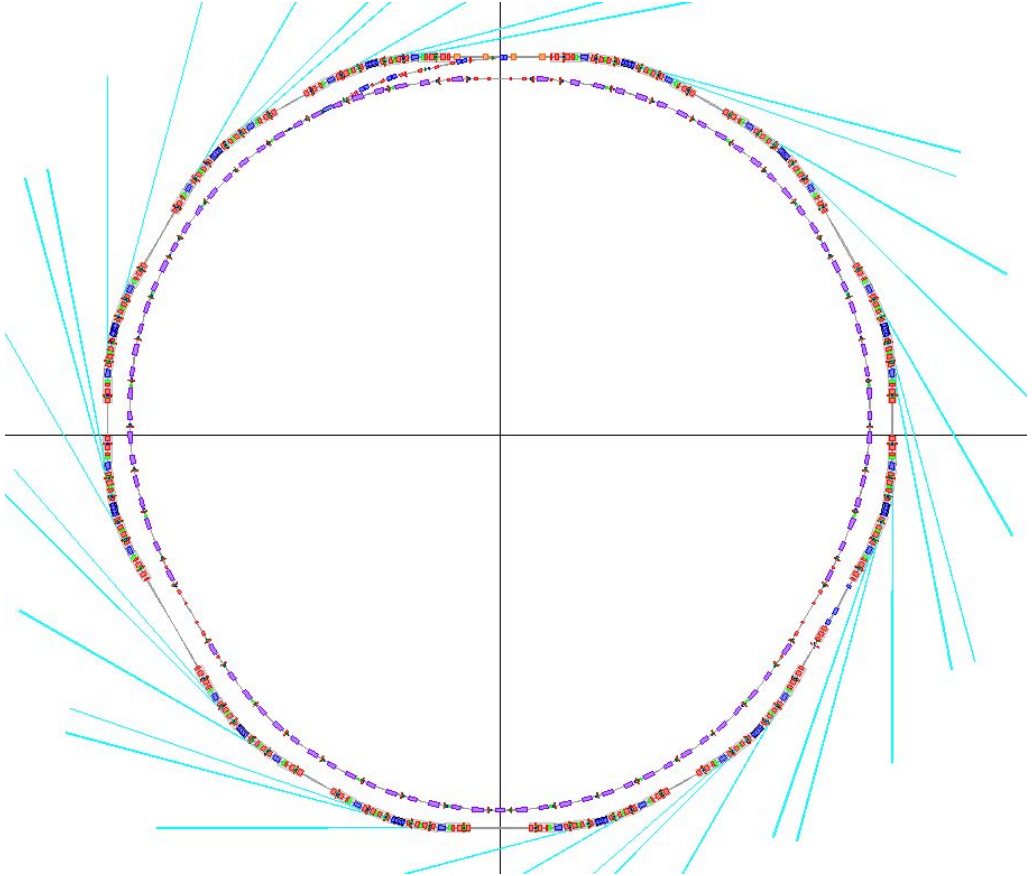
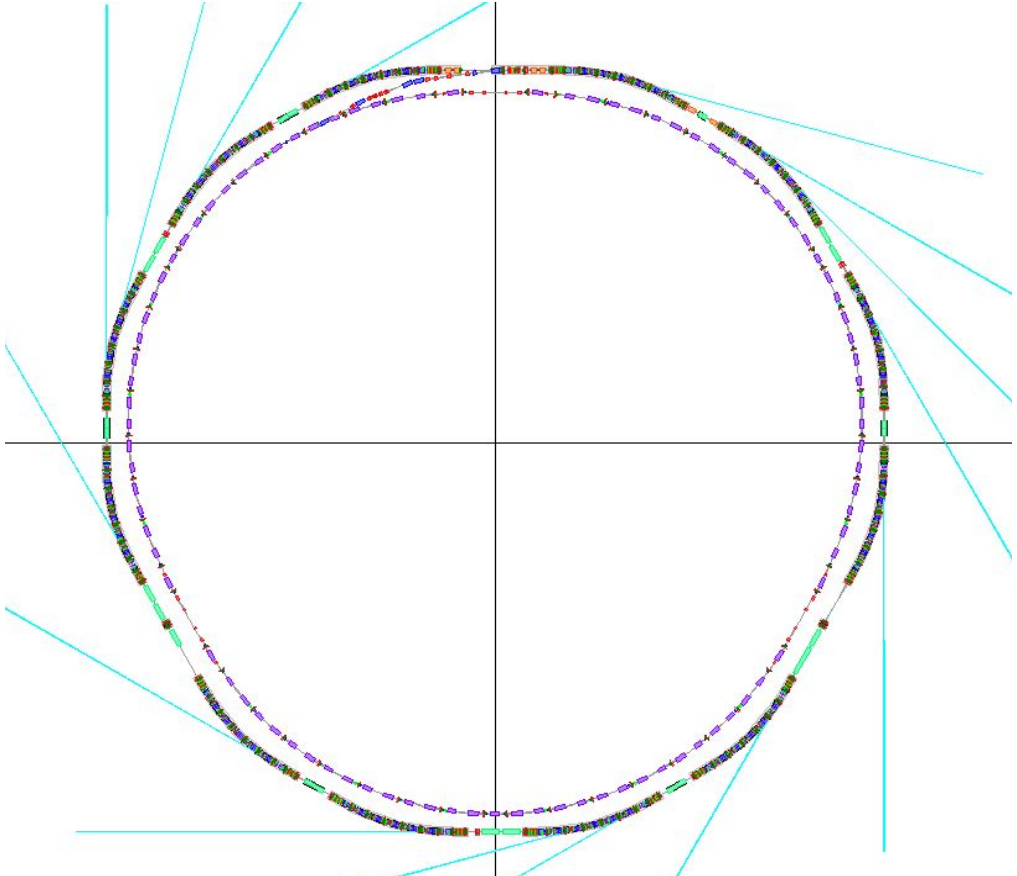


Swiss Light Source - **SLS**



- Circumference **288 m**
- Straights
  - **3** × Long
  - **3** × Medium
  - **6** × Short
  - Total Length ~ **80 m**
- Beam Current **400 mA**
- Beam Energy 2.41 GeV
- Emittance 5.5 nm

Swiss Light Source - Upgrad Project **SLS 2.0**



- **Maintained**
  - Circumference **288 m**
  - Straights
    - **3** × Long
    - **3** × Medium
    - **6** × Short
    - Total Length **~80 m**
  - Beam Current **400 mA**
- **Almost Maintained**
  - Source Point Positions |shifts| < **70 mm**
- **Improved**
  - Emittance **157 pm** (from 5500 pm)
  - Energy **2.7 GeV** (from 2.41 GeV)

SLS 2.0 Emergency Beam Dump - Comparison SLS

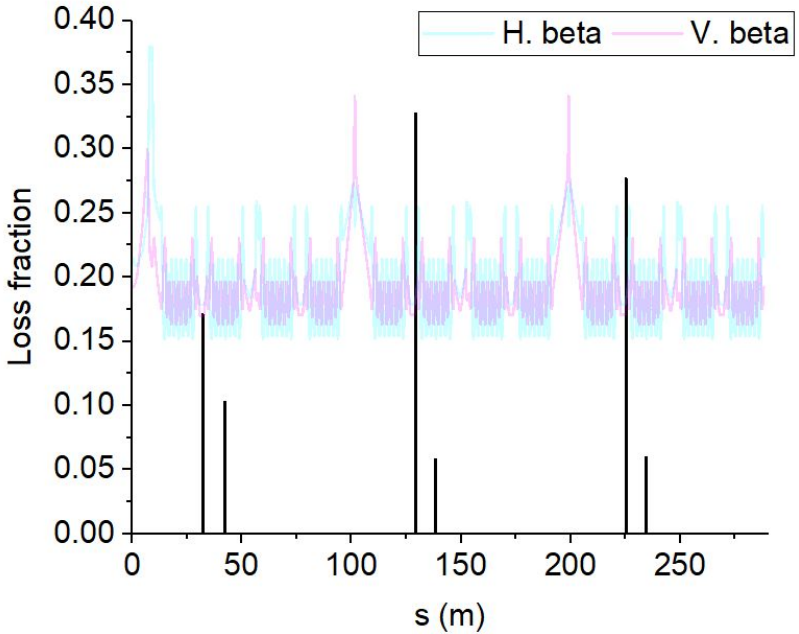
- Beam dump concept SLS
  - RF phase inversion
  - Beam is decelerated → dispersive orbit
  - Aperture limitations determine loss locations
  - Losses at septum and high-dispersion TBA arc-sections
- Machine protection main aspects
  - Synchrotron radiation
  - Beam loading

SLS 2.0 Emergency Beam Dump - Requirements

Tracking simulations show for RF phase inversion

- Unfortunate loss localization at in-vacuum undulator and SC superbend

Longitudinal distribution of beam loss after RF phase inversion



- **Low dispersion MBA arcs**
- **No “thick” vacuum chamber like for SLS**
- **Vacuum chamber only 1 or 0.5 mm thick**
- **Main losses localized at few positions including**
  - **in-vacuum ID**
  - **SC superbend**

SLS 2.0 Emergency Beam Dump - Requirements

Tracking simulations show for RF phase inversion

- Unfortunate loss localization at in-vacuum undulator and SC superbend
  - ➔ **RF phase inversion beam dump of SLS not applicable**
- RF trip causes beam loss after 300 turns
  - ➔ **Beam dump delay < 300 µs required**
  - ➔ **Fast beam dump controller bypassing slow PLC systems required**

Destructive potential of stored beam

- Emittance 157 pm (from 5500 pm)
- 400mA @ 2.7GeV (from 2.4 GeV) = 1 kJ beam energy
- APS tungsten scraper experiments (2 kJ)
- SPring-8 Injection chamber vacuum leak with low-emittance optics (4 kJ)
  - ➔ Controlled beam dump with dedicated kicker, dump and “bunch painting”

SLS 2.0 Emergency Beam Dump - Requirements

Tracking

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  - ➔
- RF
  - ➔
  - ➔

Destruct

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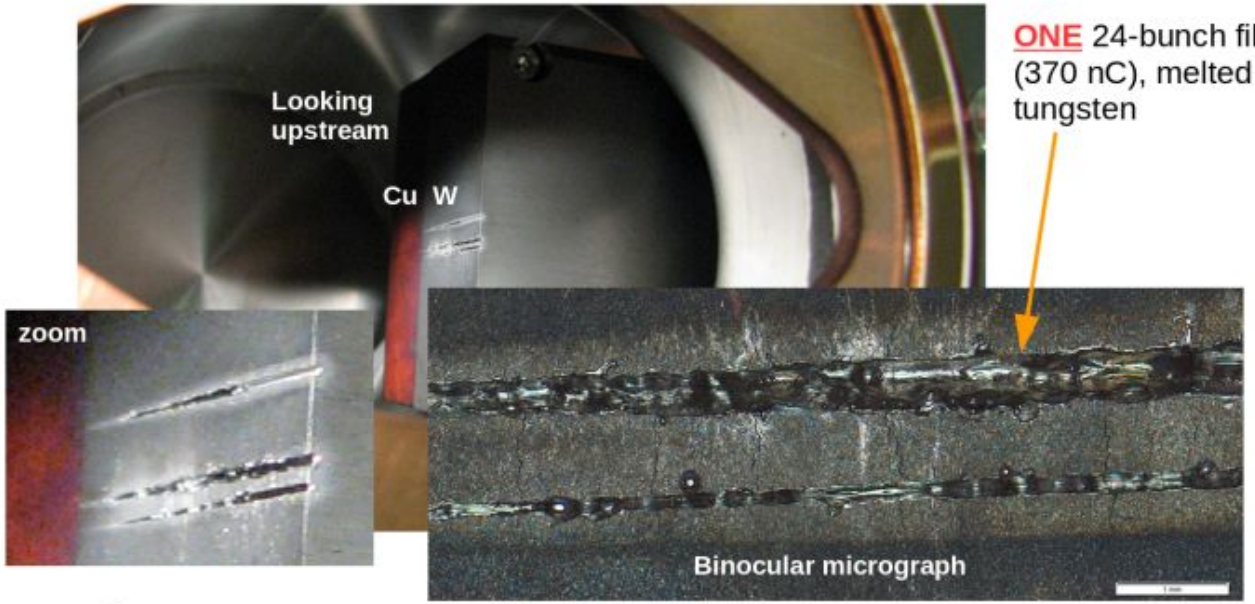
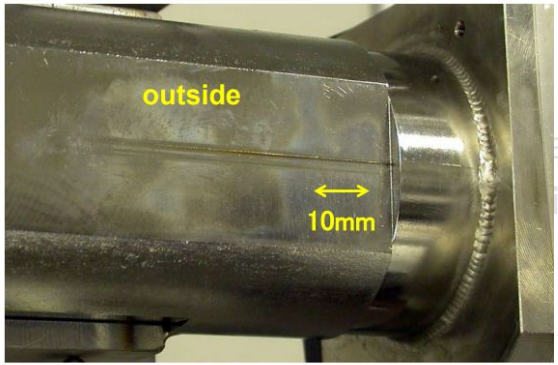
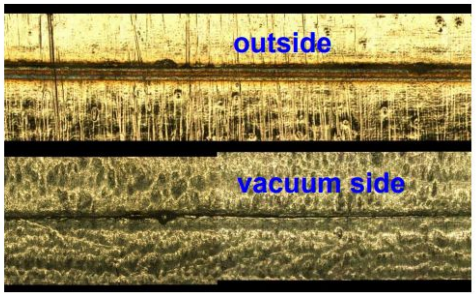


- **APS tungsten scraper experiments (2 kJ) [1, 2]**
- SPring-8 Injection chamber vacuum leak with low-emittance optics (4 kJ)
  - ➔ Controlled beam dump with dedicated kicker, dump and “bunch painting”

[1] J. Dooling & M. Borland, *Energy Deposition in the APS-U swap-out dump and discussion of whole beam loss*, Technical Workshop on Injection and Injection Systems, August 28-30, 2017, Berlin, Germany
[2] *Advanced Photon Source Upgrade Project*, Final Design Report, May, 2019, Chapter 2: Accelerator Upgrade, 2-2.9 Beam Dumps and Collimation, 2-2.9.4 Whole-beam dump, P.42

SLS 2.0 Emergency Beam Dump - Requirements





- **SPring-8 Injection chamber vacuum leak with low-emittance optics (4 kJ) [3]**
  - ➔ Controlled beam dump with dedicated kicker, dump and “bunch painting”

[3] H. Tanaka et al., *Top-Up Operation of SPring-8 Storage Ring with Low-Emittance Optics,* Proceedings of EPAC 2006, Edinburgh, Scotland, THPLS034

SLS 2.0 Emergency Beam Dump - Requirements

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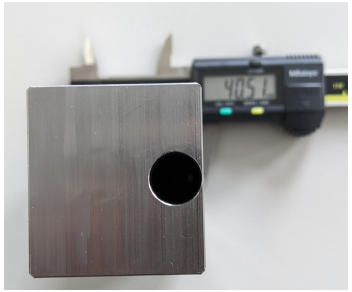
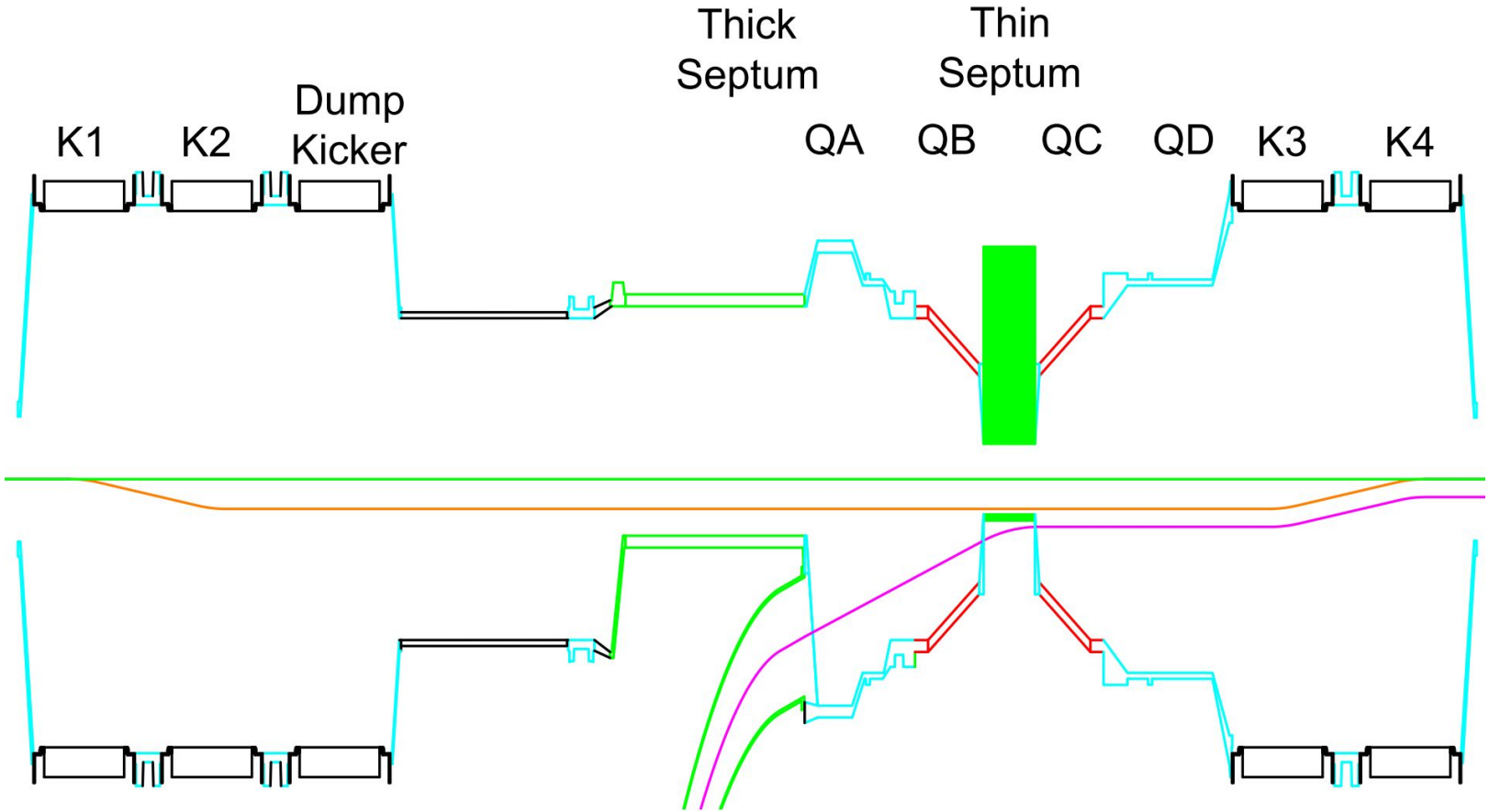
SLS 2.0 Emergency Beam Dump - Concept

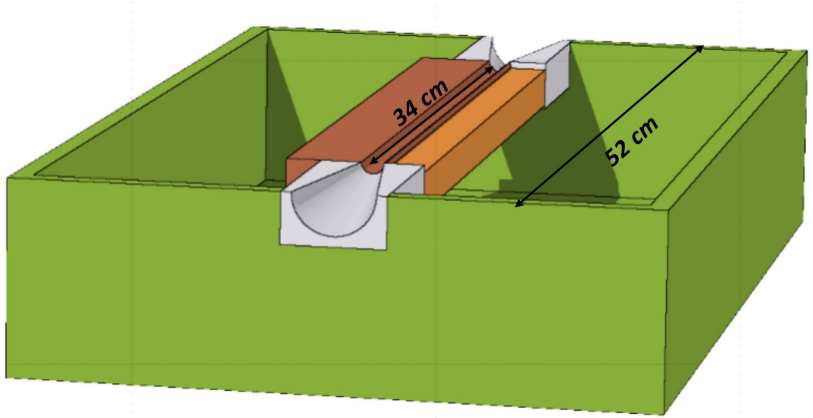


- Fast beam dump controller (delay < 100 ns)
- Dedicated Beam dump
  - Upstream tapering element of thin septum (aluminium)
  - Thin septum block (iron)
- Dedicated vacuum valve in injection straight
- Dedicated beam dump kicker in injection straight
  - ~4 μs half sine, ~2.1 mrad
    - Kick variation along bunch train
      - First ~100 bunches lost at thin septum after 2 turns (= 2 kicks)
      - Next ~30 bunches lost at 9L collimator directly
      - Next ~50 bunches lost at 5L collimator directly
      - Last ~300 bunches lost at thin septum directly
    - 80 - 90% lost at dump and 10 - 20% at collimators

SLS 2.0 Emergency Beam Dump - Concept



SLS 2.0 Emergency Beam Dump - Beam Dump

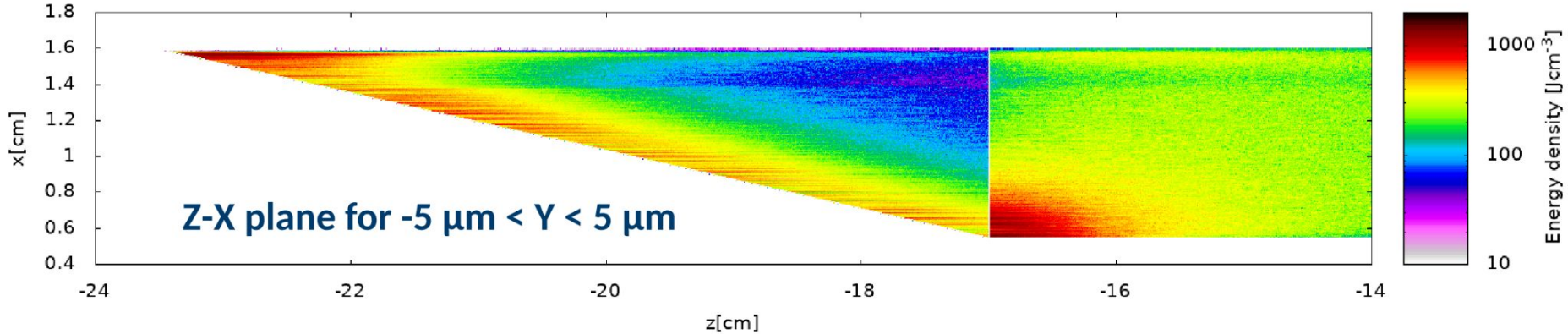


Preliminary results

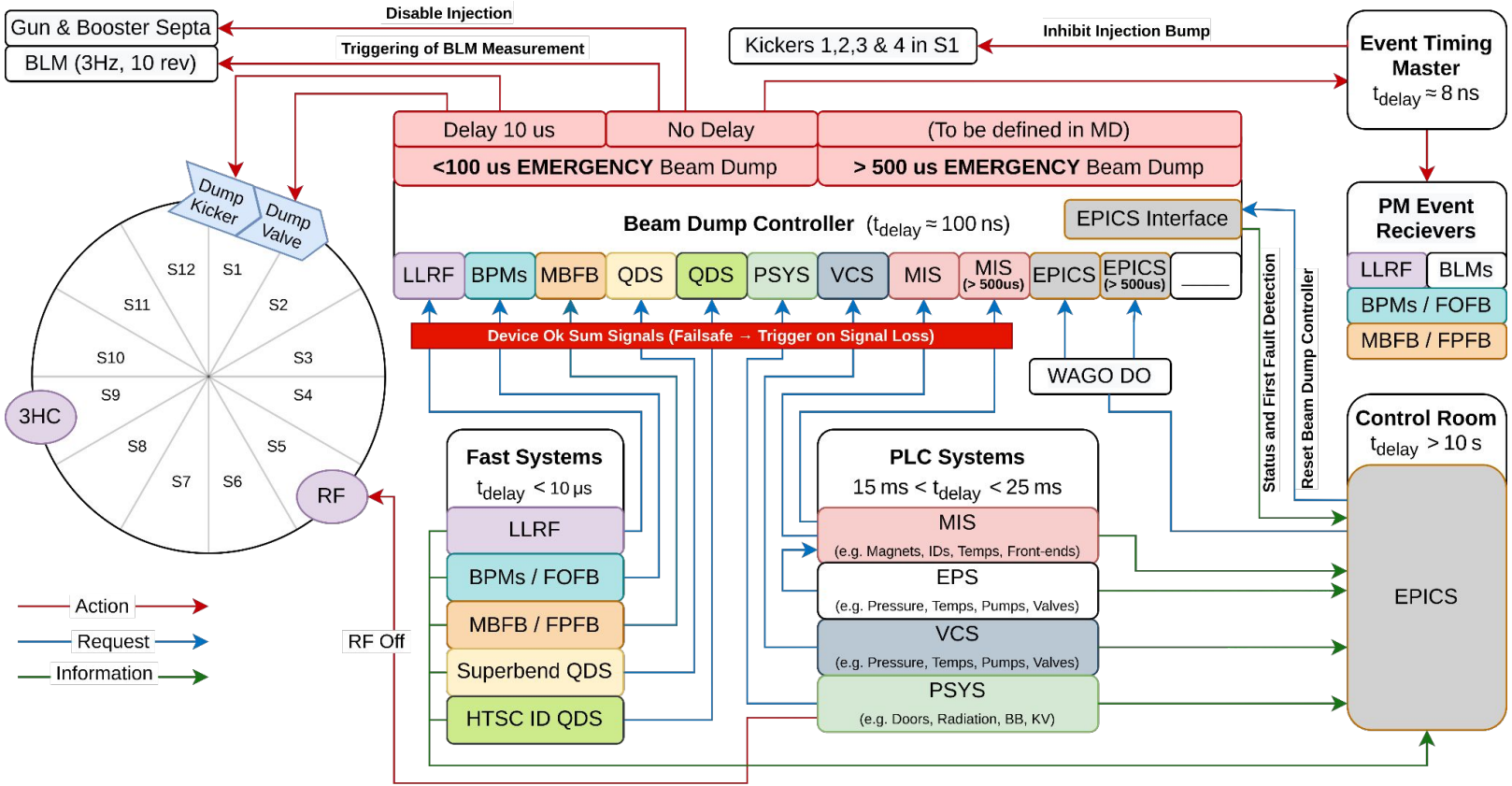
- Energy densities upto **~2000 J / cm^3 ?**
- Dose on tunnel roof **200 µSv >> 10 µSv**
- Dose outside tunnel **0.5 to 1 µSv**
- Weekly limit of **20 µSv**

Challenges

- Shielding
- Material damage on surface
- Limit activation



SLS 2.0 Emergency Beam Dump - Overview



SLS 2.0 Emergency Beam Dump - Controller

Main function

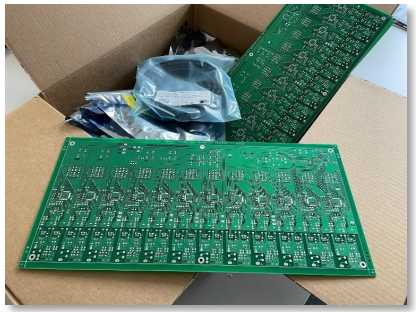
- Combine signals of critical systems
- Trigger a controlled beam dump

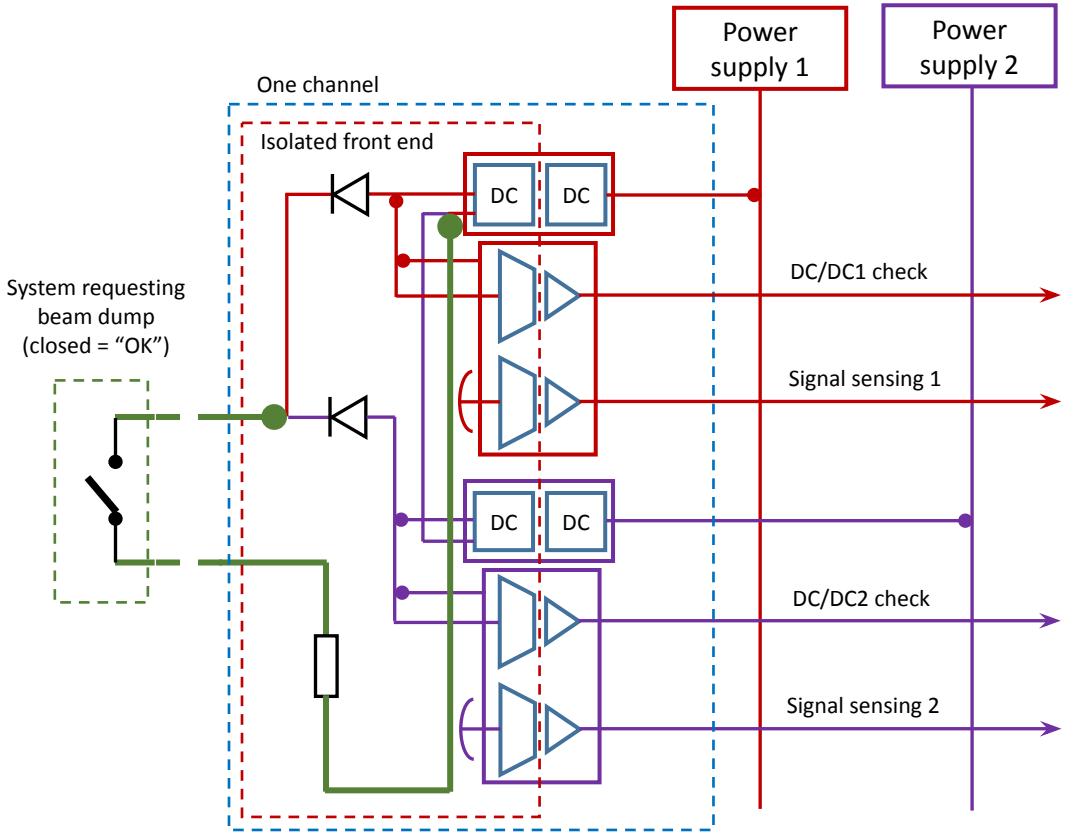
Requirements

- Reliability
- Fail-safe logic
- Fast reaction time
- Compatibility with variety of systems

New feature

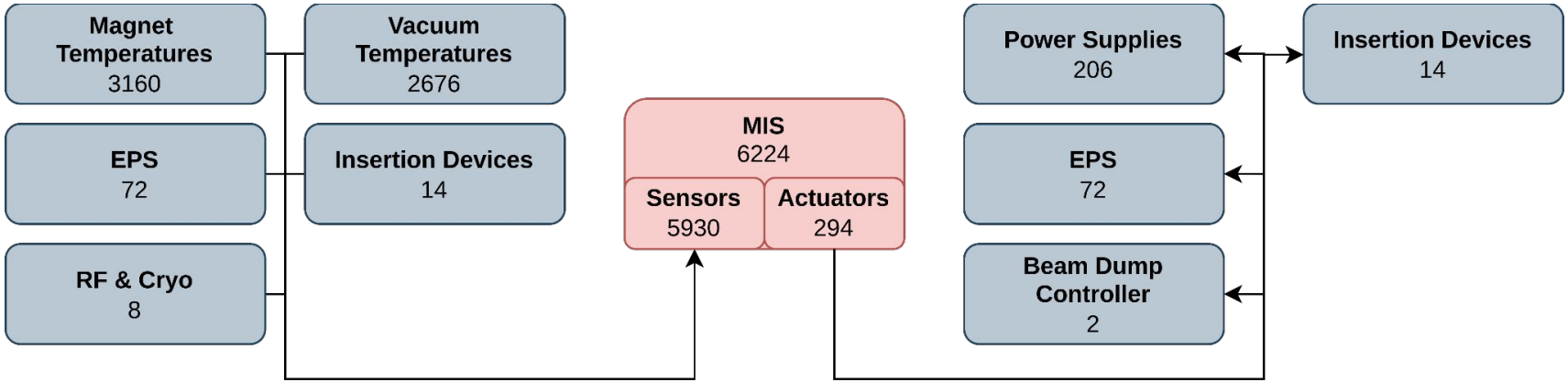
- Registration of the dump requests order and relative arrival time





Schematic representation of an individual channel input

SLS 2.0 Emergency Beam Dump - Main PLC System



The **M**achine **I**nterlock **S**ystem

- Monitors the sensors and provides beam permits to the actuators
- Storage ring sensor signals in the tunnel are combined via profinet
- Extrapolating from experience with the SLS MIS, 90 dumps / year are expected

Summary

- **Beam dump concept**
  - Avoid dispersive beam loss (300 µs)
  - Dedicated kicker and dump with “bunch painting”
- **Beam dump controller**
  - Fast, fail-safe and reliable
  - EPICS integration
- **Machine interlock system with 6200 signals**
  - Avoid false interlocks
- **Beam dump**
  - Shielding of radiation outside of tunnel
  - Avoid damage to taper and thin septum block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Thank you for your attention!
Thanks to all who contributed to this talk!
M. Aiba
I. M. Besana
C. Gough
M. Paraliev
C. Stettler
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