



MAX 4^U



An Upgrade of the MAX IV 3 GeV Ring

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on behalf of MAX 4^U team

11th March 2026

MAX IV

Outline

- Introduction
- Why MAX 4^U?
- MAX 4^U Technical design studies.
- The way ahead.

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MAX IV



- **The Swedish national laboratory for X-ray research with Lund University as host.**
- **Operates the 1st fourth-generation light source in the world**
- **Inaugurated June 2016**
- **16 beamlines in user operations**
- **>1900 users/year from 35 countries**
- **42% Swedish users.**
- **~5000 hours of delivery, ~98% uptime**

MAX IV



The MAX IV Accelerators

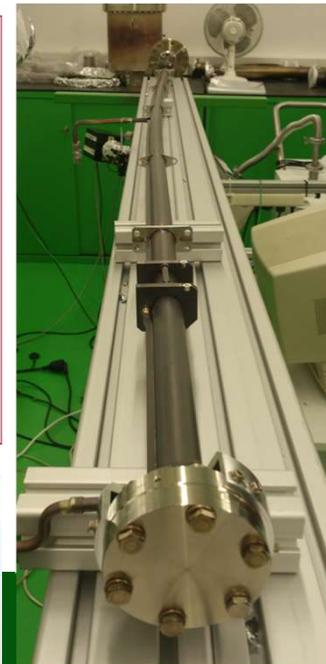
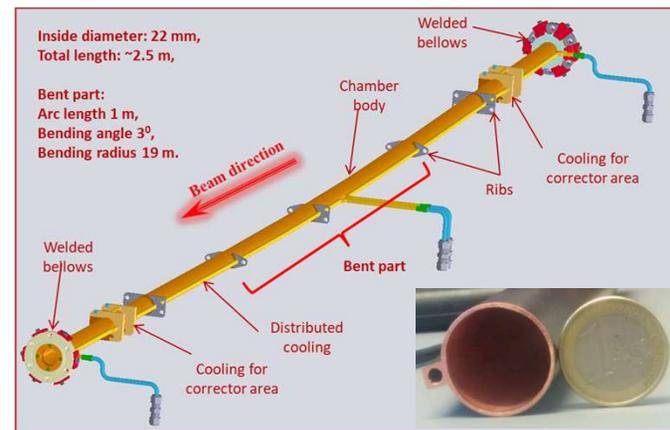
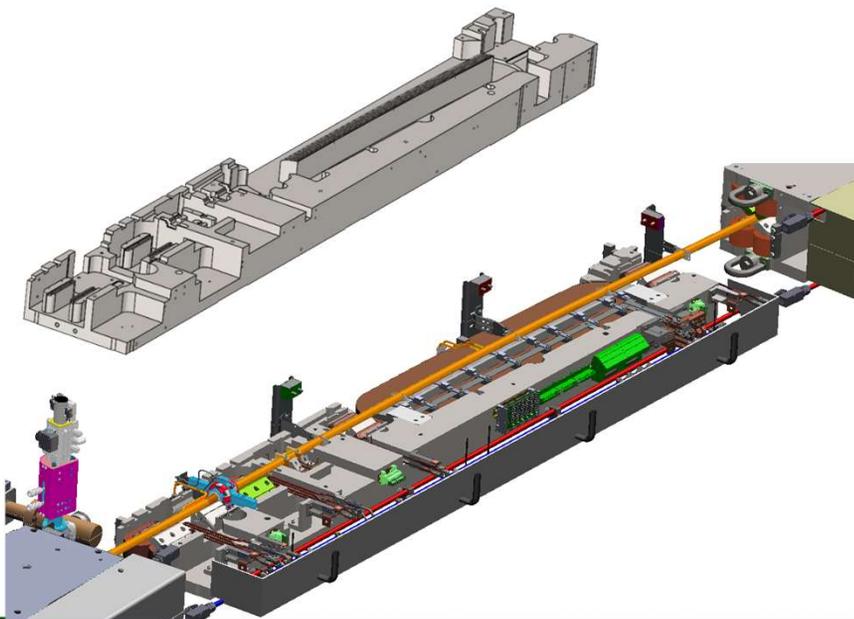
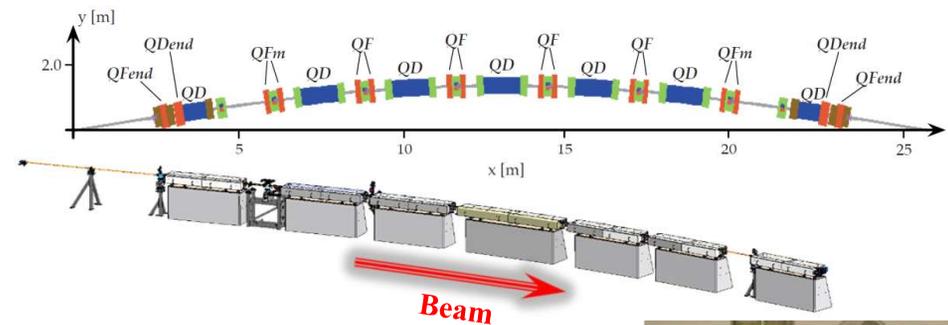


MAX IV 3GeV ring layout

20 achromats

7-bend achromat lattice, 1 achromat ~26m long

MAX IV subsystems: magnet blocks and vacuum chambers



Outline

- Introduction
- **Why MAX 4^U?**
- MAX 4^U technical design studies.
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2026

10

years since the first MAX IV
beamline became operational

40

years of scientific activity

SYDSVENSKAN

Malmö Lund Sydsvenskan Direkt Sport Dygnet runt Kultur Opinion Mer E-tidning

Lund >

Hjärnan bakom Maxlab

5 september 2011 07:37

– Lund är lite 60-tal. Det bara ångar på hela tiden, säger Mikael Eriksson som är mannen bakom Maxlab.

Jan Samuelsson
Text



Mikael Eriksson byggde delar till Max 1 på en väns mangel.
Bild: Foto: Amelie Herbertsson

– Med Max I–III har vi legat jämsides med de andra anläggningarna. Med Max IV kommer vi att hamna före alla andra.



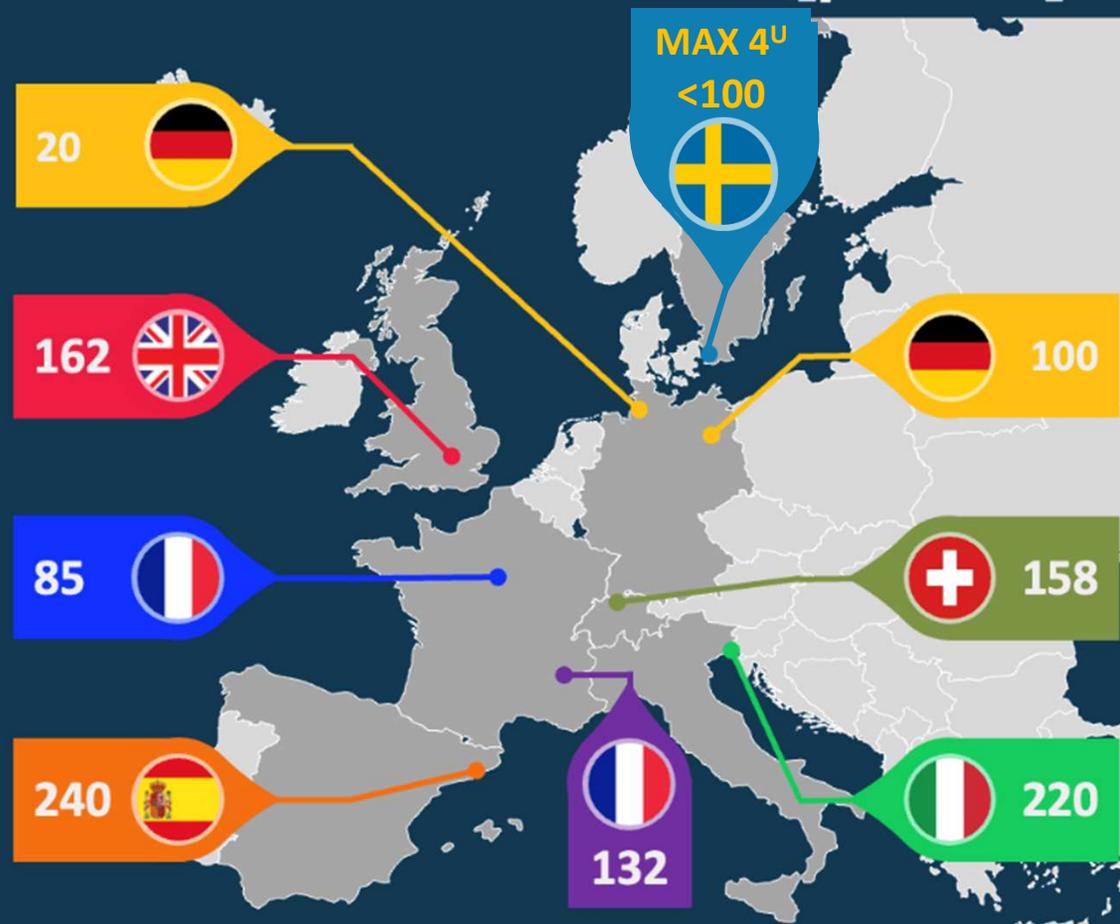
Why MAX 4^U ?

European Context
in >2030

MAX IV
9

MAX 4^U – “surgical” upgrade of the MAX IV 3 GeV ring

Horizontal Emittance [pm·rad]



Outline

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MAX 4^U Goals and Boundary Conditions

- MAX 4^U is ***NOT a conventional upgrade***, which requires the replacement of most components.
- MAX 4^U is a ***surgical intervention*** to provide an outstanding performance improvement while maintaining much of the existing hardware.
- How come this is at all possible?
 - The **original MAX IV 3 GeV ring design** foresaw upgrade options in various ways.
 - Various **innovative schemes** (*ultralong bunches, advanced injection methods*)
 - MAX 4^U can take advantage of **new developments in the accelerator community** in recent years.

MAX 4^U Goals and Boundary Conditions

- Emittance \lesssim **100 pmrad**.
- Keep the shielding wall
- Keep the injector: accumulation
- Keep existing light source positions
- Limited dark period
- Cost-effective
- Realisable until the early part of the next decade



Conceptual Design Report

December 24, 2025

Conceptual Design Report (CDR) Completed December 24th, 2025:

<https://www.maxiv.lu.se/beamlines-accelerators/max-4u/accelerator-design/>

The screenshot shows a web browser displaying the MAX IV website. The URL in the address bar is [maxiv.lu.se/beamlines-accelerators/max-4u/accelerator-design/](https://www.maxiv.lu.se/beamlines-accelerators/max-4u/accelerator-design/). The page features a navigation menu with categories: USER ACCESS, SCIENCE, BEAMLINES & ACCELERATORS, EDUCATION & OUTREACH, and INDUSTRY. The breadcrumb trail is: Start > Beamlines & accelerators > MAX 4U > Accelerator Design. The main heading is "Accelerator Design" under the "MAX 4U" section. The content includes the title "Conceptual Design Report for MAX 4U" and a summary: "The Conceptual Design Report outlines a strategy to reduce the natural emittance of the 3 GeV ring from 328 pm-rad to below 100 pm-rad. The upgrade is carefully designed to meet strict limits on cost, installation time, and operational downtime. By preserving the shielding wall, source points and injector, MAX 4^U maximises performance gains while minimising disruption and cost." A "Contacts" sidebar on the right lists "MAX 4U" and the email address MAX4U@maxiv.lu.se.

Current MAX 4^U Goals and Boundary Conditions

- Emittance \lesssim ~~100 pmrad.~~ **75 pmrad.**
- Keep the shielding wall
- Keep the injector: accumulation
- Keep existing light source positions
- Limited dark period
- Cost-effective
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MAX 4^U Lattice, 65 pm.rad



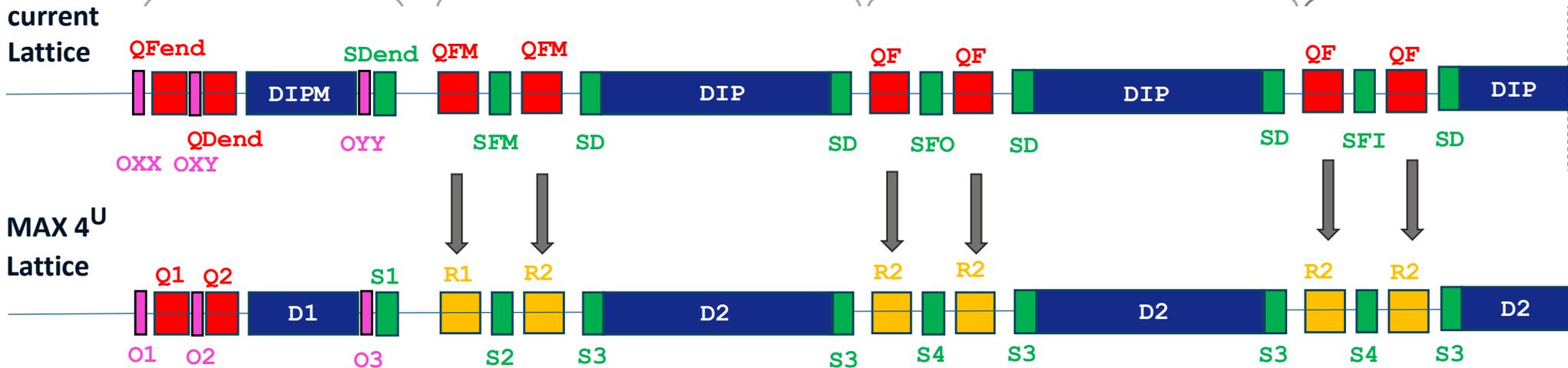
Half achromat:

MC1

UC1

UC2

half UC3



12 horizontally focussing quadrupoles are turned into reverse bends grouped into two families.

Magnet blocks

- Solid low-carbon steel
- Integrated consecutive magnet elements
- Split in beam plane

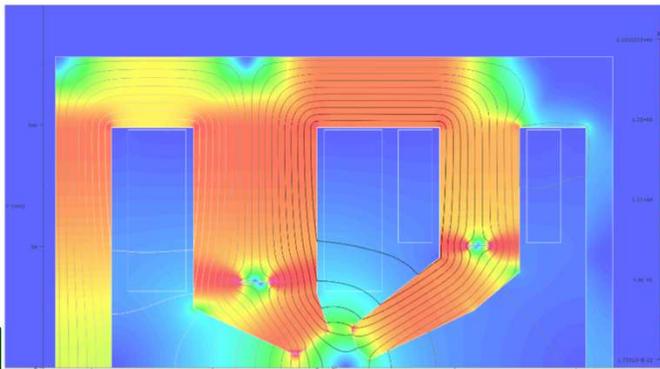
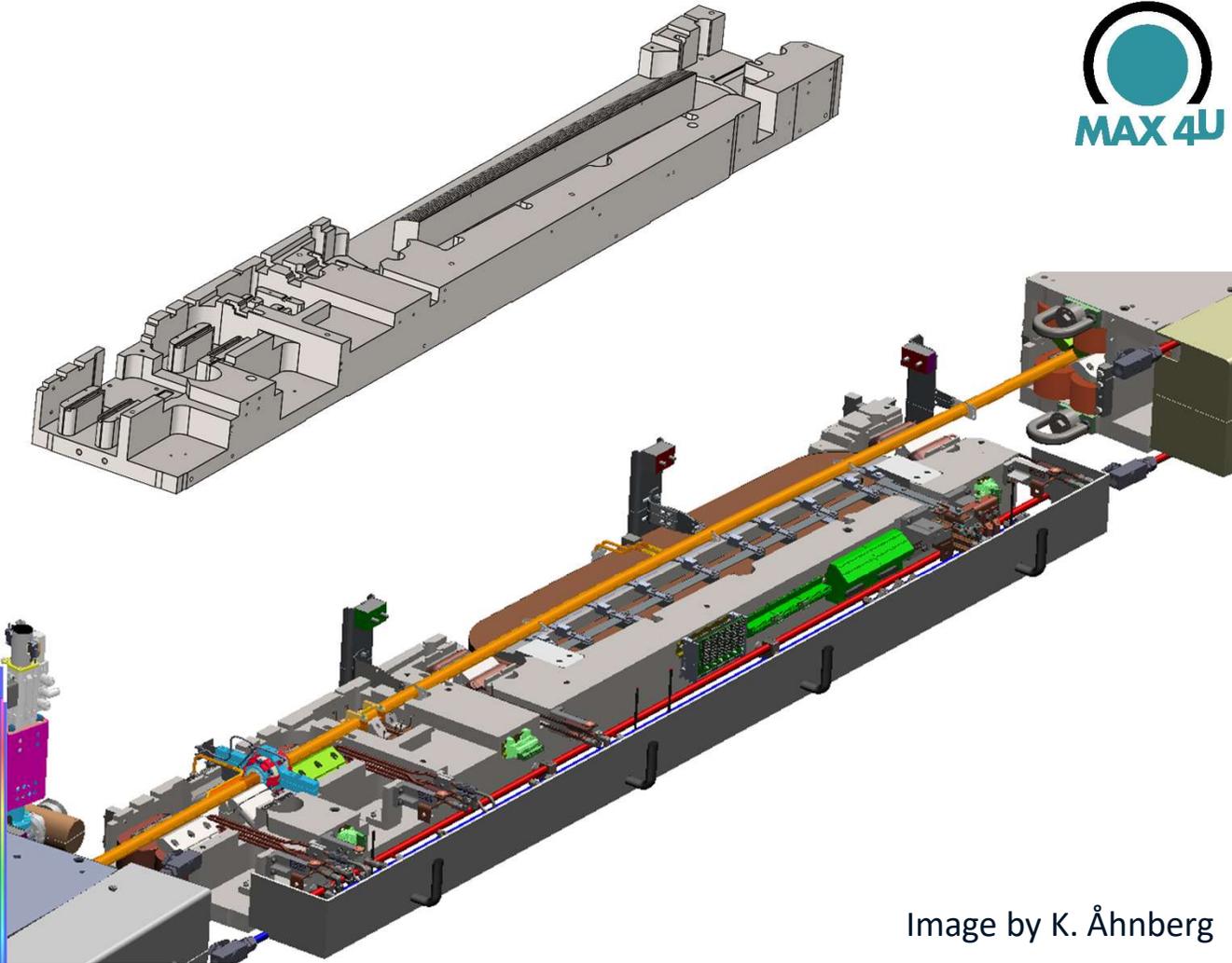
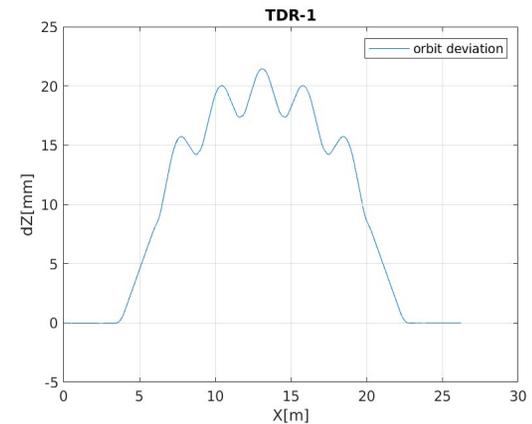
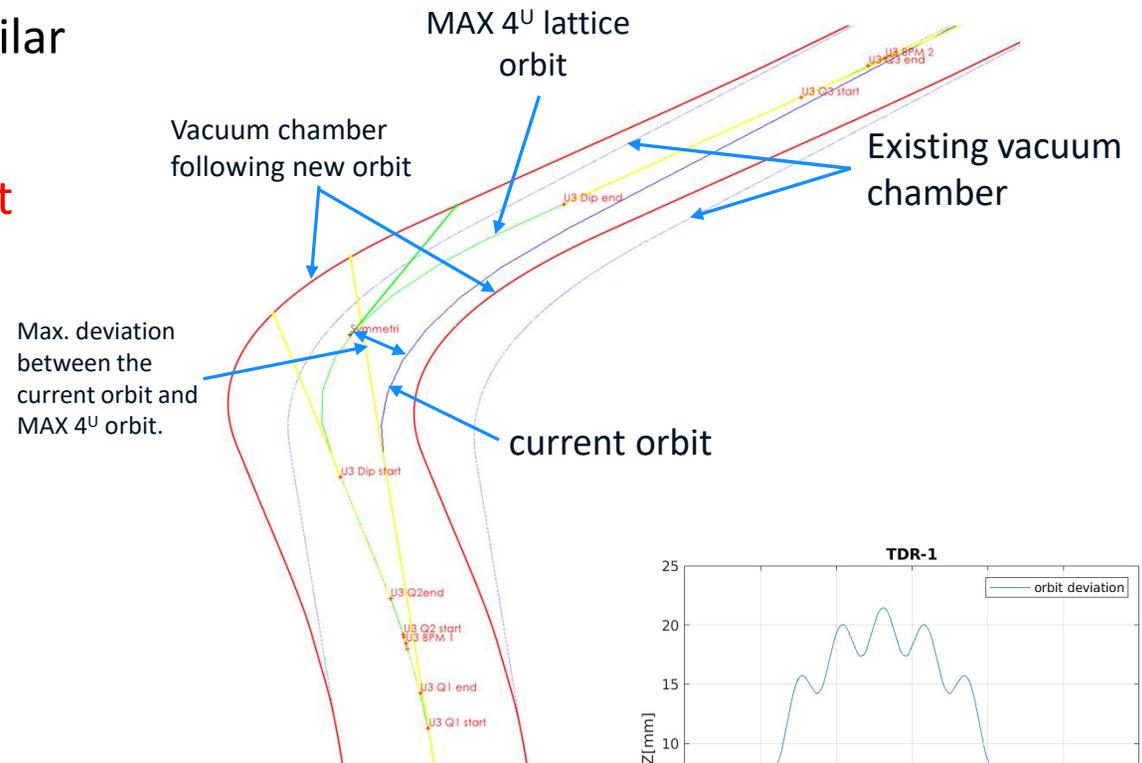


Image by K. Åhnberg

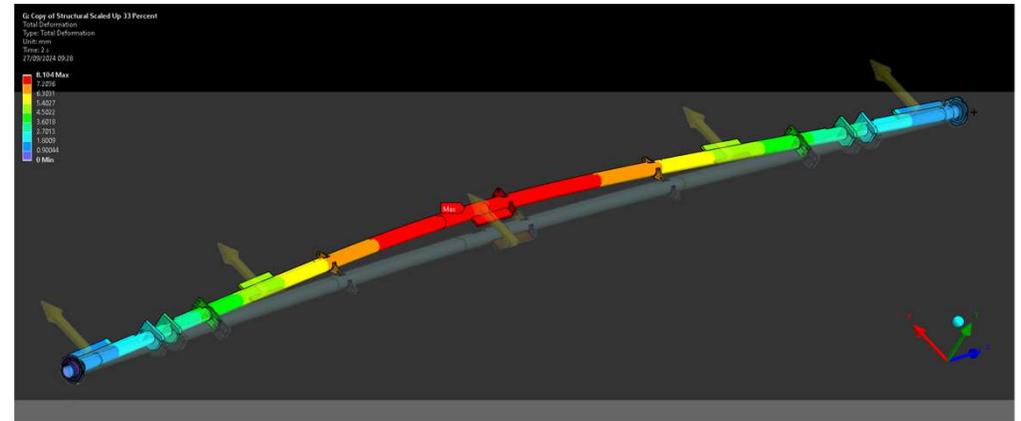
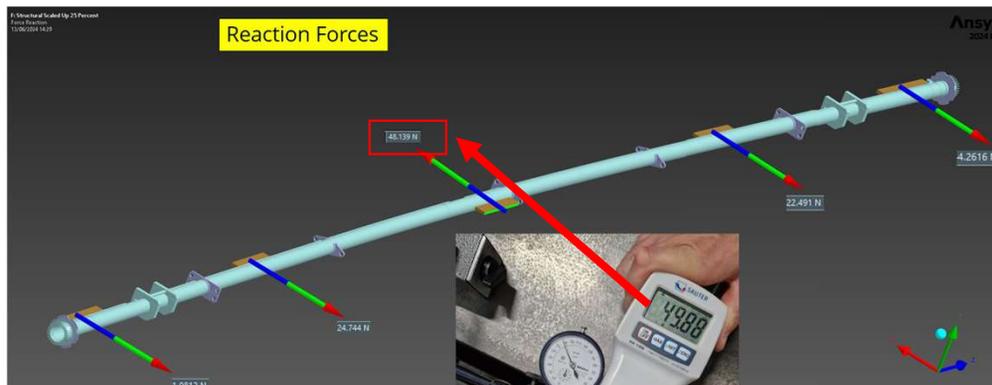
Vacuum System: chamber design

- The new chambers would be VERY similar to the existing ones.
- Why not **keep the chamber and bend it into the new shape?**
- Do not even need to break vacuum.
 - *Cheaper*
 - *Faster to install*
 - *Faster conditioning*



Vacuum Chambers

- Bending to fit the new lattice
- Reusing some of the existing chambers



c/o Pablo Sanchez Navarro, Karl Åhnberg

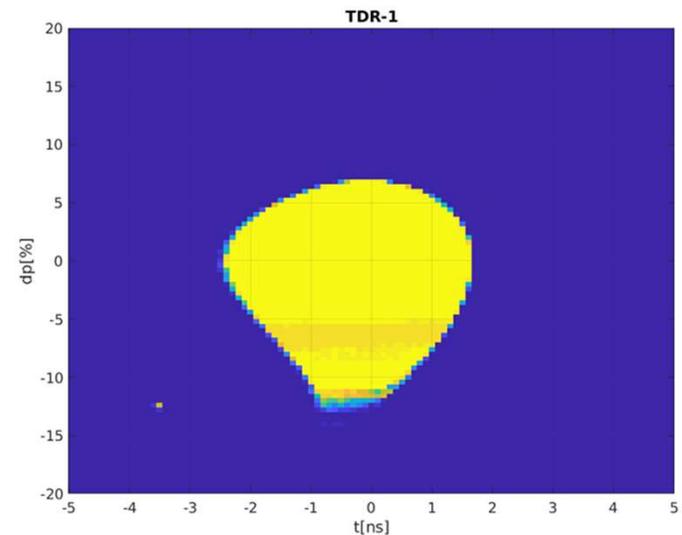
Off-phase Injection

Off-phase injection /accumulation into MAX 4^U is enabled by

- **Full energy injector linac:** small injected beam phase-space volume.
- **Low RF frequency (100 MHz):** longer time in-between electron bunches in the ring

Off-phase injection allows:

- Better top-up transparency
- Small horizontal aperture insertion devices
- Accumulation into restricted dynamic aperture



Challenges

- **Accelerator Physics:**

- Obtaining enough phase acceptance to capture the beam stably

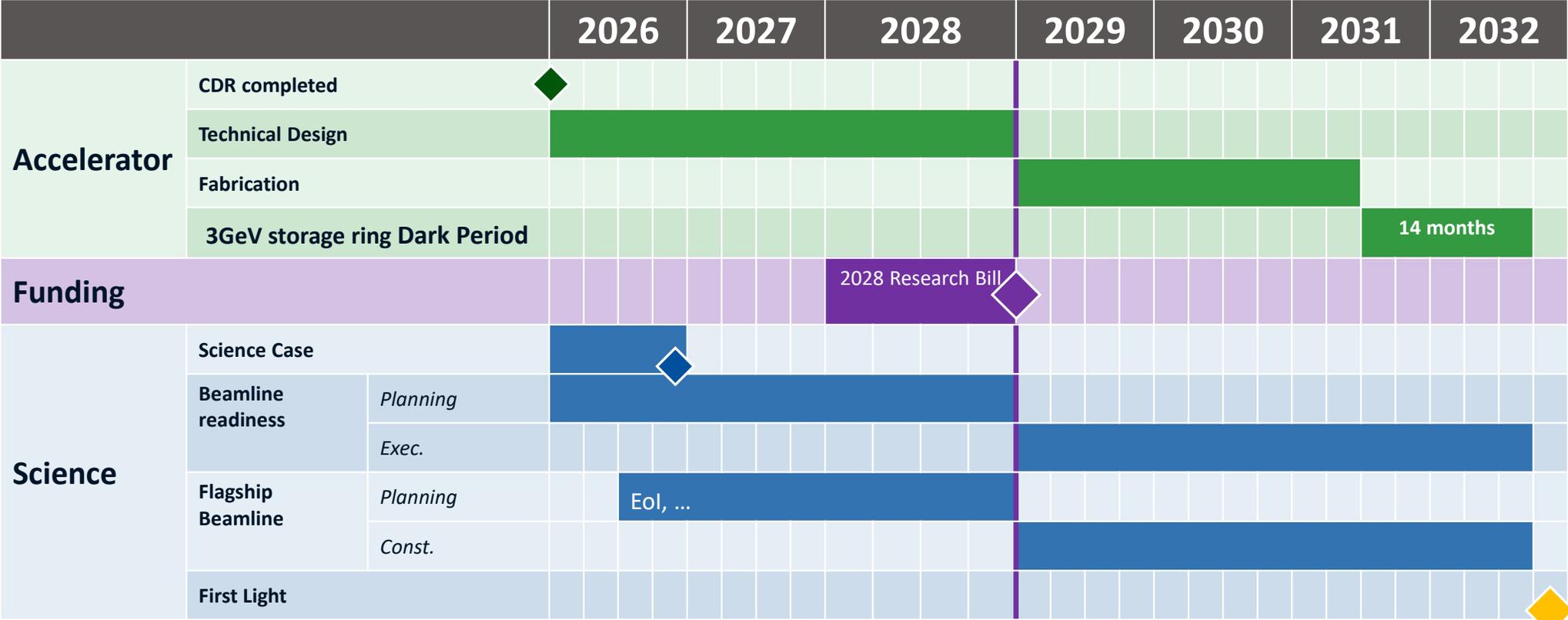
- **Accelerator Engineering:**

- Building the required high voltage (\sim tens of kV), fast (\sim ns fall time) pulsers.
- Appropriate high-voltage vacuum feedthroughs
- Building the required striplines without excessively creating too much impedance for the beam

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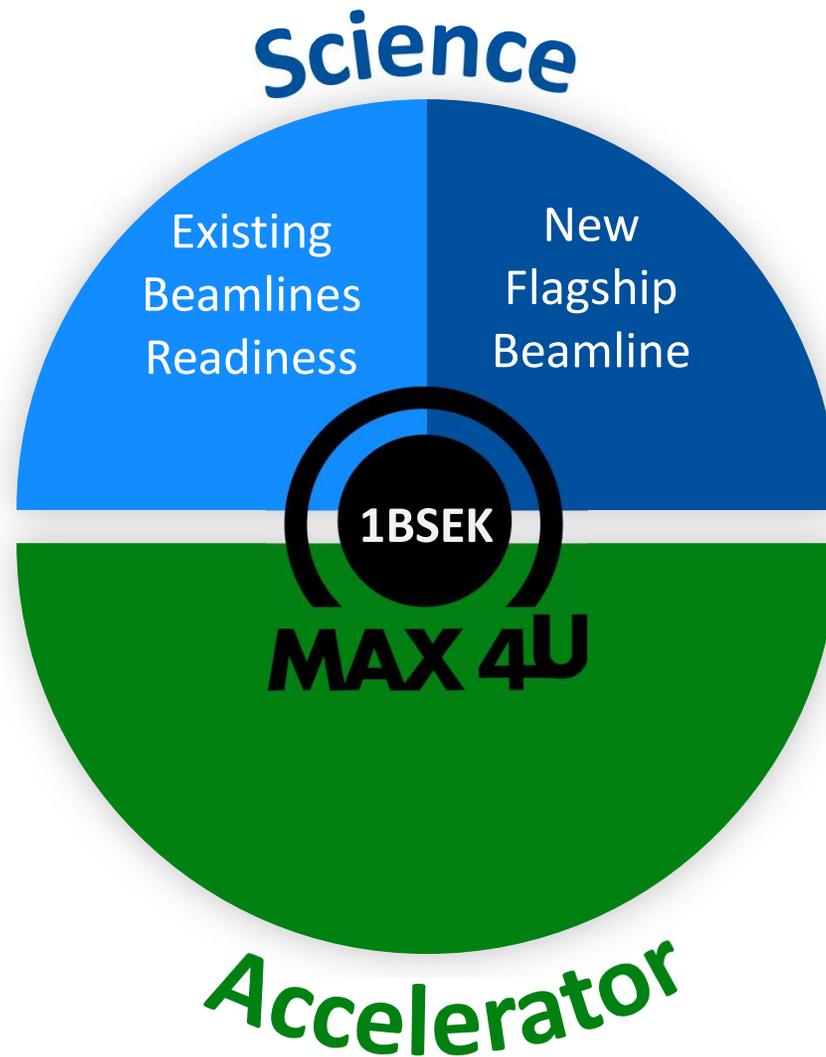
Schedule



No downtime for 1.5 GeV storage ring or SPF



Budget



Opportunities for the industry



Accelerator needs

- **Magnets:**
 - Magnet blocks
 - Magnet power supplies.
- **Vacuum:**
 - Vacuum chambers
 - bellows.
 - Vacuum gauges and thermocouples.
- **Diagnostics:**
 - Beam Position Monitors (BPM) and PS/controllers.
- **Injection**
 - Pulsed striplines (with 20 kV feedthroughs)
 - HV Pulsers (~20 kV, rise/fall-time < 2ns)
- **Installation**
 - Assembly tools.
 - Bakeout ovens.
 - Magnet installation tools and trucks.
- **Assembly services:**
 - Heavy lifting.
 - Technical installation.
 - Cooling/cabling installation.
- **Radiological waste disposal and management.**
- And more...

Beamlines needs

- **Optics**
 - X-ray mirror systems
 - Grating optics
 - Compound refractive lenses (CRL) and transfocators
 - Crystal optics for monochromators
- **Detectors**
 - Hybrid-pixel area detectors
 - Charge-integrating detectors
 - X-ray beam monitors
- **Sample scanning systems**
 - Nano-positioning
 - Tomography systems
- **Sample environments and experiments**
 - Experiment heaters
 - Cryostats
 - Gas-control systems
 - Gas detection
- **Chopper and triggering systems**
- **Computing**
 - Expand high-speed data analysis clusters
- And more...

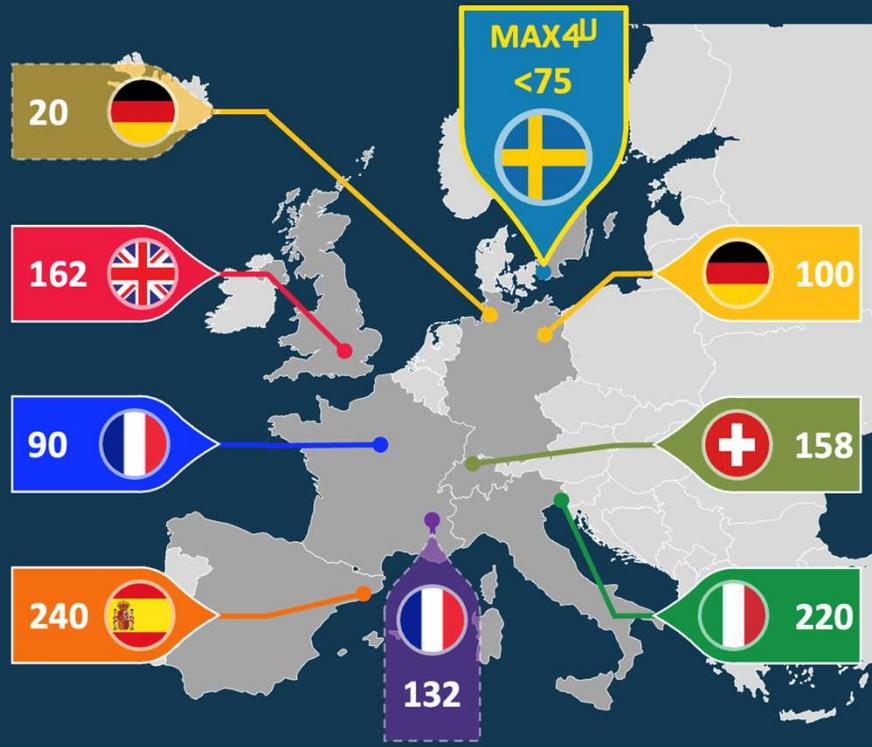
MAXIV

2032

MAX 4U



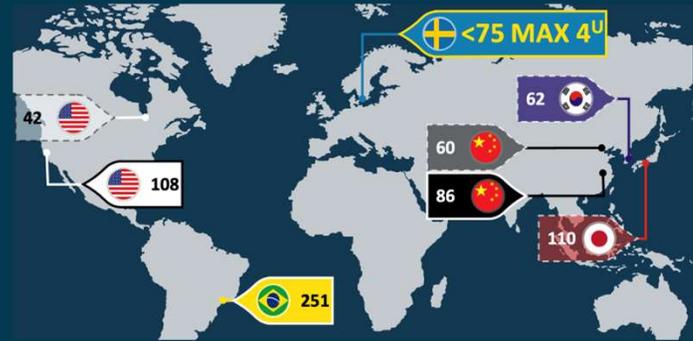
Horizontal Emittance [pm·rad]



Securing leadership, excellence, resilience, and relevance of Swedish research an innovation with X-rays for the next decades



MAX 4U website



A "surgical" upgrade of our 3GeV ring from 328 to below 75 pm·rad