

# The European Spallation Source



EUROPEAN  
SPALLATION  
SOURCE

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NIKHEF  
industriemiddag  
21 september 2011

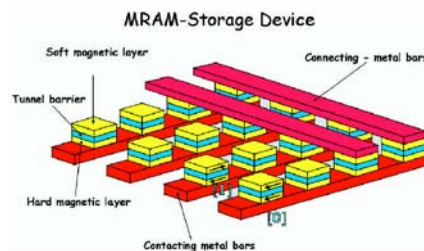
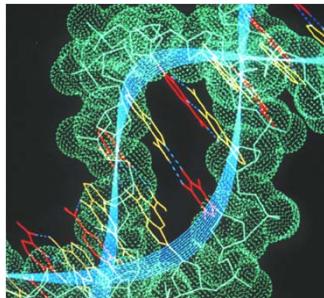
# The European Spallation Source



Materials science  
Energy Technology

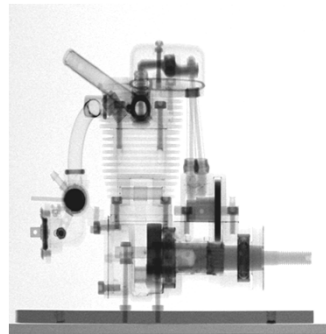
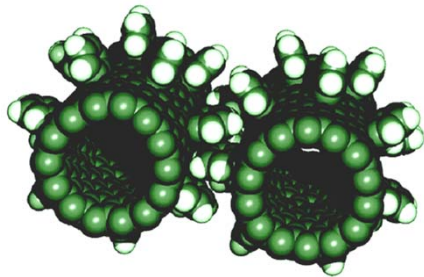
Bio-technology  
Hardware for IT

Nano science  
Engineering science

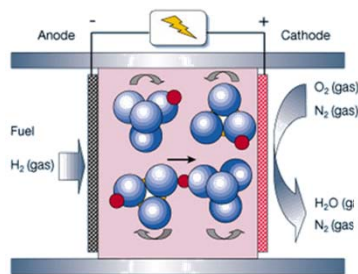


- Neutrons can provide unique and information on almost all materials.

- Information on both structure and dynamics simultaneously. "Where are the atoms and what are they doing?"



- 5000 users in Europe today  
Access based on peer review.



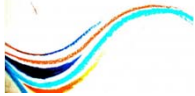
- Science with neutrons is limited by the intensity of today's sources



Courtesy M. Lindroos

# Neutrons are multi-faced

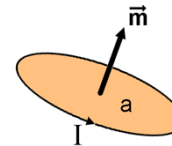
Wave



Particle



Magnetic moment

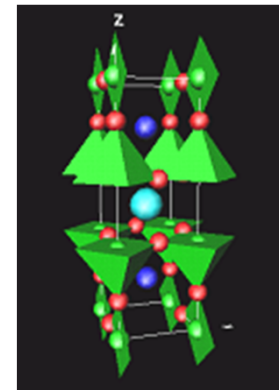


Neutral



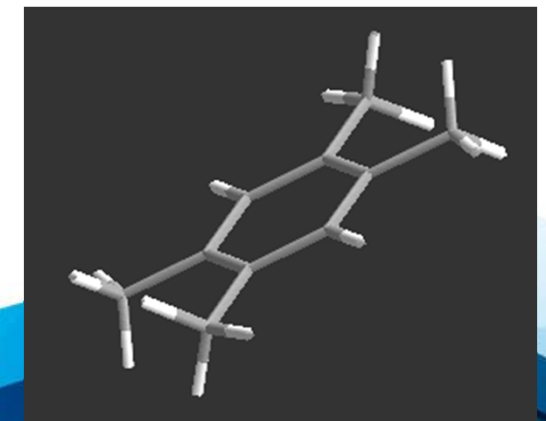
Diffractometers - Measure structures  
– Where atoms and molecules are

1 - 10 Ångström



Spectrometers - Measure dynamics  
– What atoms and molecules do

1 - 80 meV

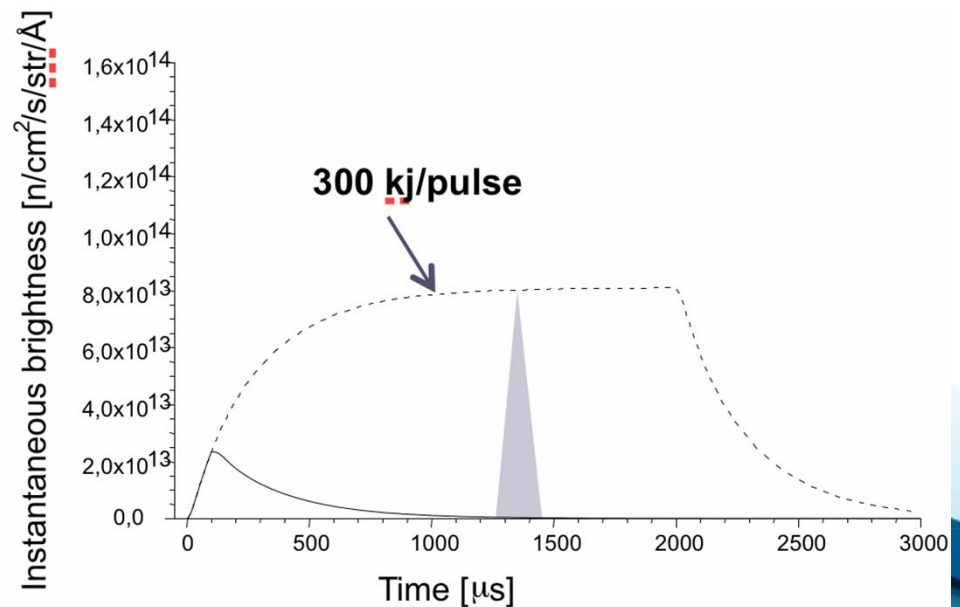




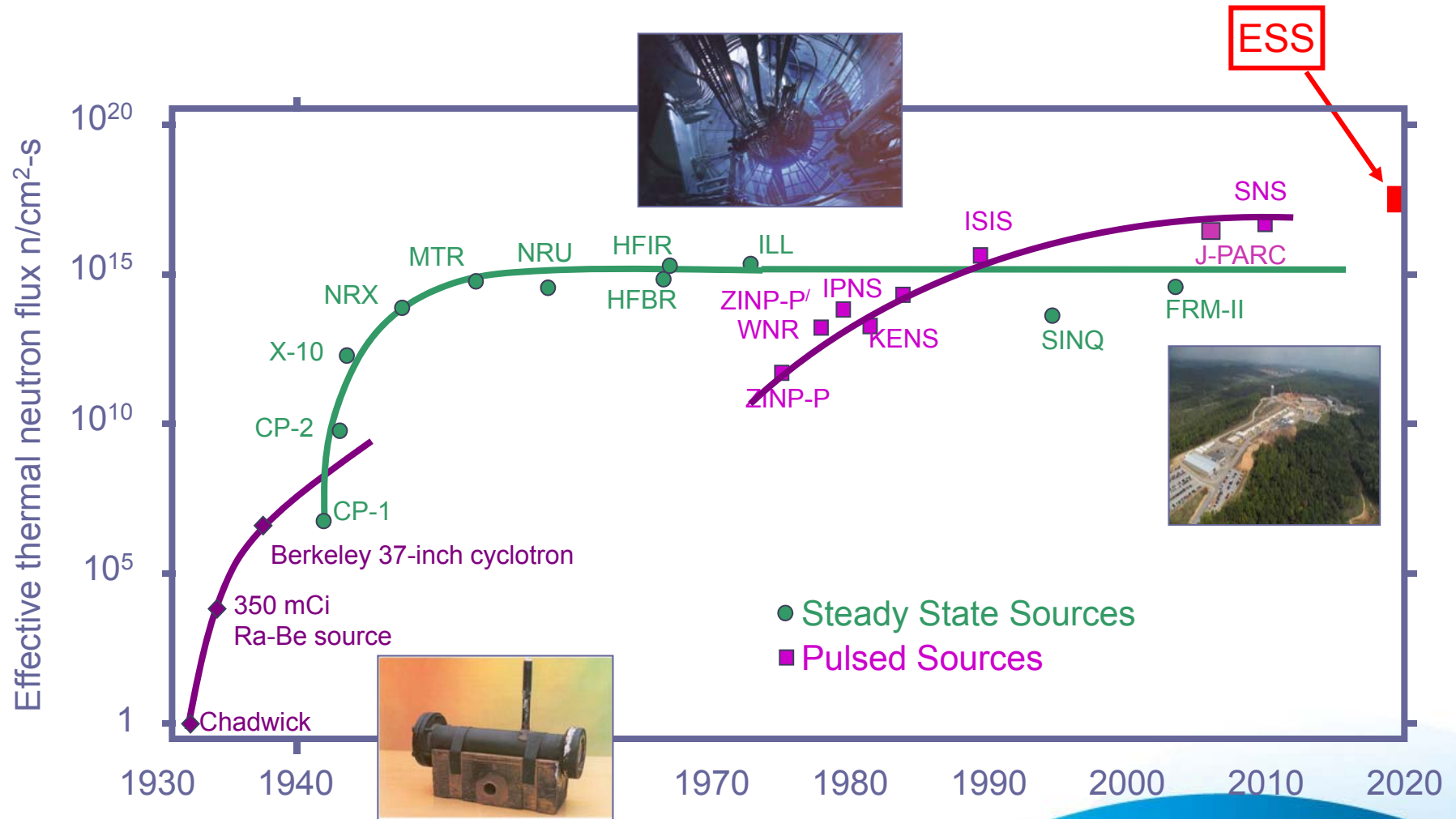
- Many research reactors in Europe are aging & will close before 2020
  - Up to 90% of their use is with **cold neutrons**
- There is a urgent need for a new high flux **cold neutron** source
  - Most users are fully satisfied by a **long pulse** source
  - Existing **short pulse** sources (ISIS, JPARC, SNS) can supply the present and imminent future need of short pulse users

*“Pulsed cold neutrons will always be long pulsed as a result of the moderation process”*

F. Mezei, NIM A, 2006

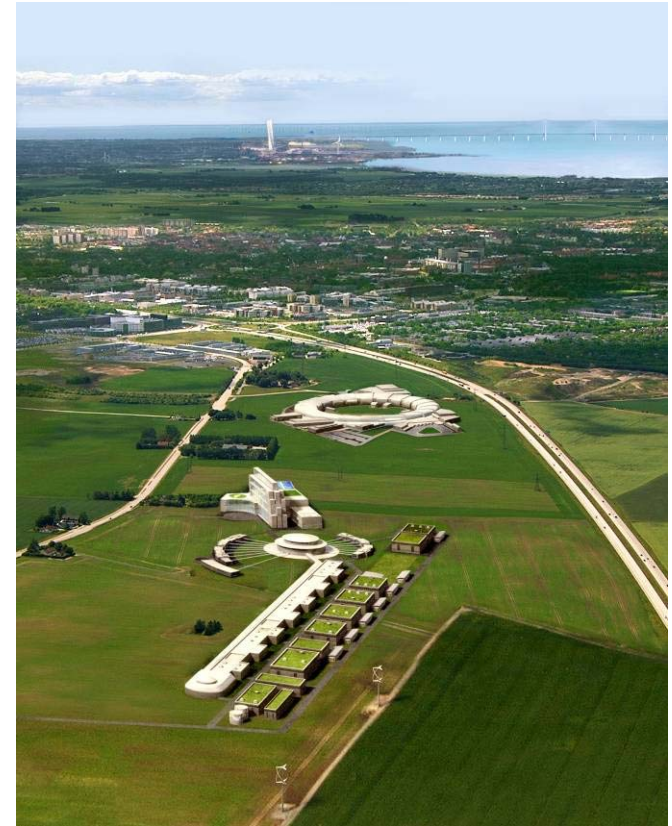


# Evolution of Neutron Sources



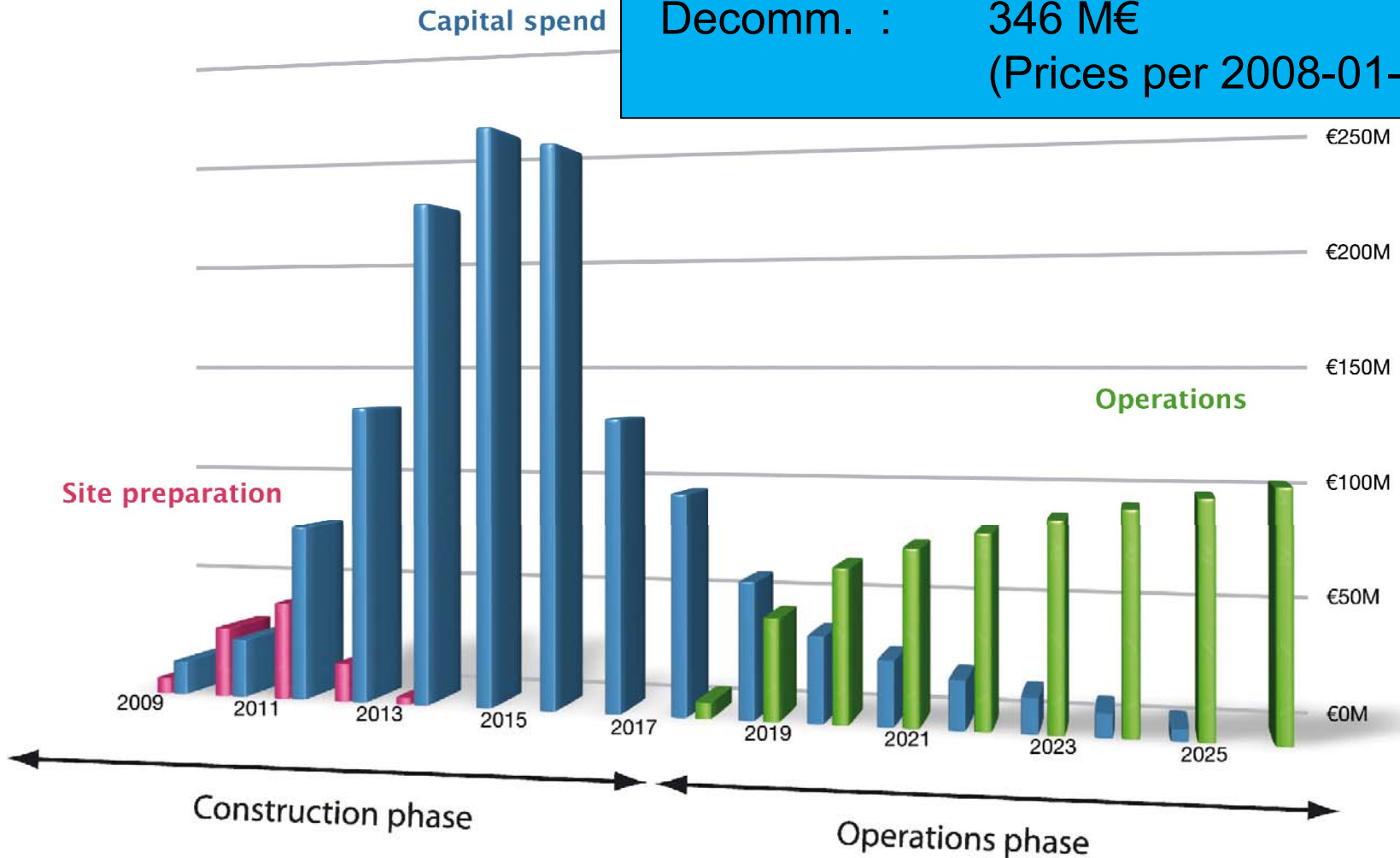
(Updated from *Neutron Scattering*, K. Skold and D. L. Price, eds., Academic Press, 1986)

- Lund, Sweden, next to MAX-IV
- 5 MW pulsed neutron source
  - 14 Hz rep. rate, 4% duty factor
  - >95% reliability for user time
- Cost estimates (2008 prices)
  - 1,5 G€ / 10 years
- Time frame:
  - 2 years design update (TDR)  
(overlap with 5y prepare-to-build)
  - 5 years construction
  - first neutrons 2019
- High intensity allows studies of
  - complex materials, weak signals, time dependent phenomena



# ESS Cost Estimates

**Investment:** 1478 M€ / ~10y  
**Operations:** 89 M€ / y  
**Decomm. :** 346 M€  
 (Prices per 2008-01-01)







EUROPEAN  
SPALLATION  
SOURCE

# International Collaboration



UPPSALA  
UNIVERSITET

Sweden, Denmark and Norway  
covers 50% of cost



17 Partners today



The remaining ESS members states  
together with EIB cover the rest!



# ESS Layout and Energy Usage

~30 MW

Liquifiers  
69 GWh/y

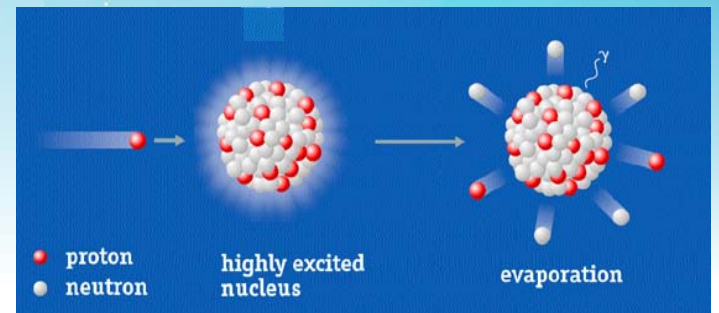
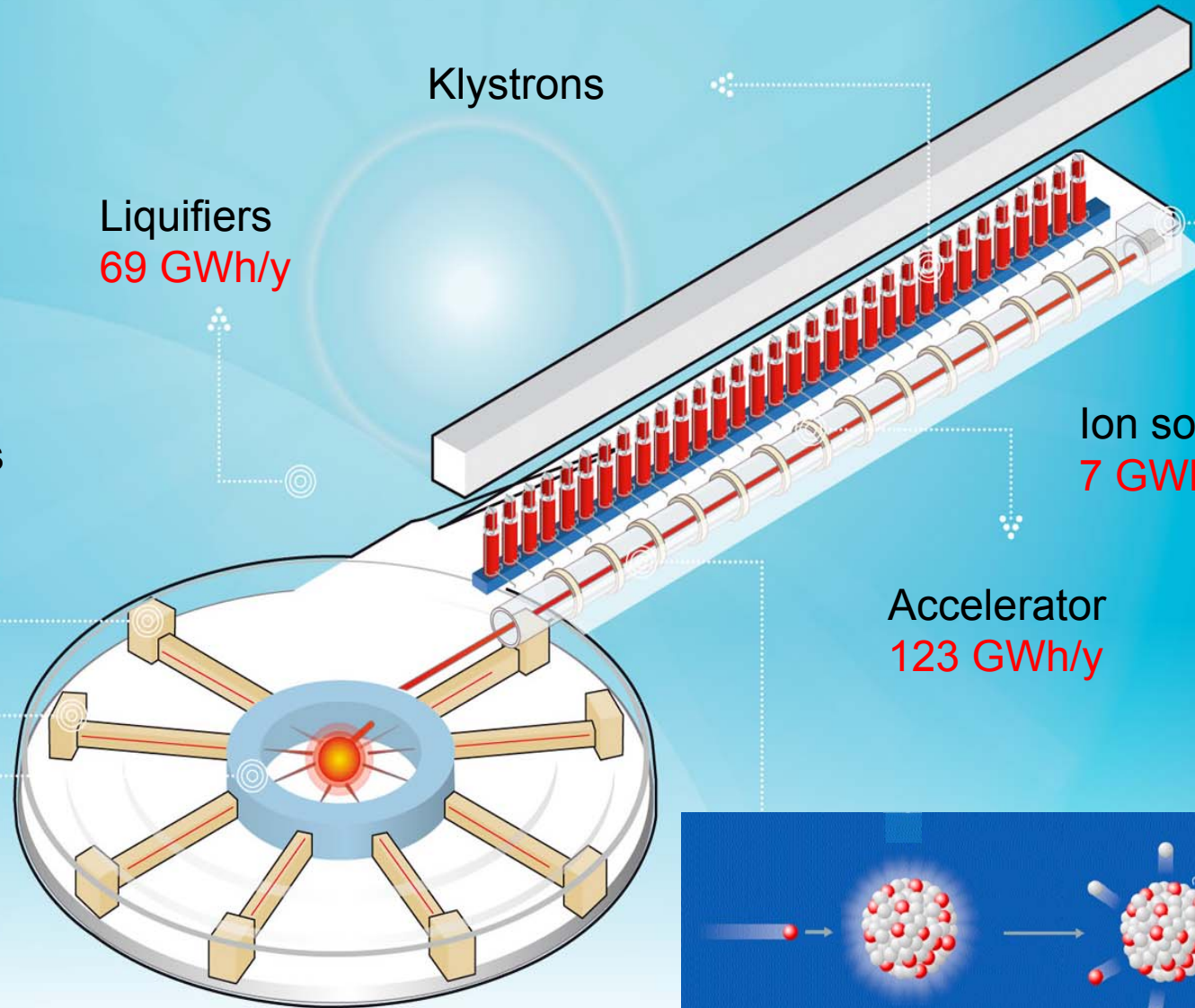
Instruments  
5 GWh/y

Target station  
11 GWh/y

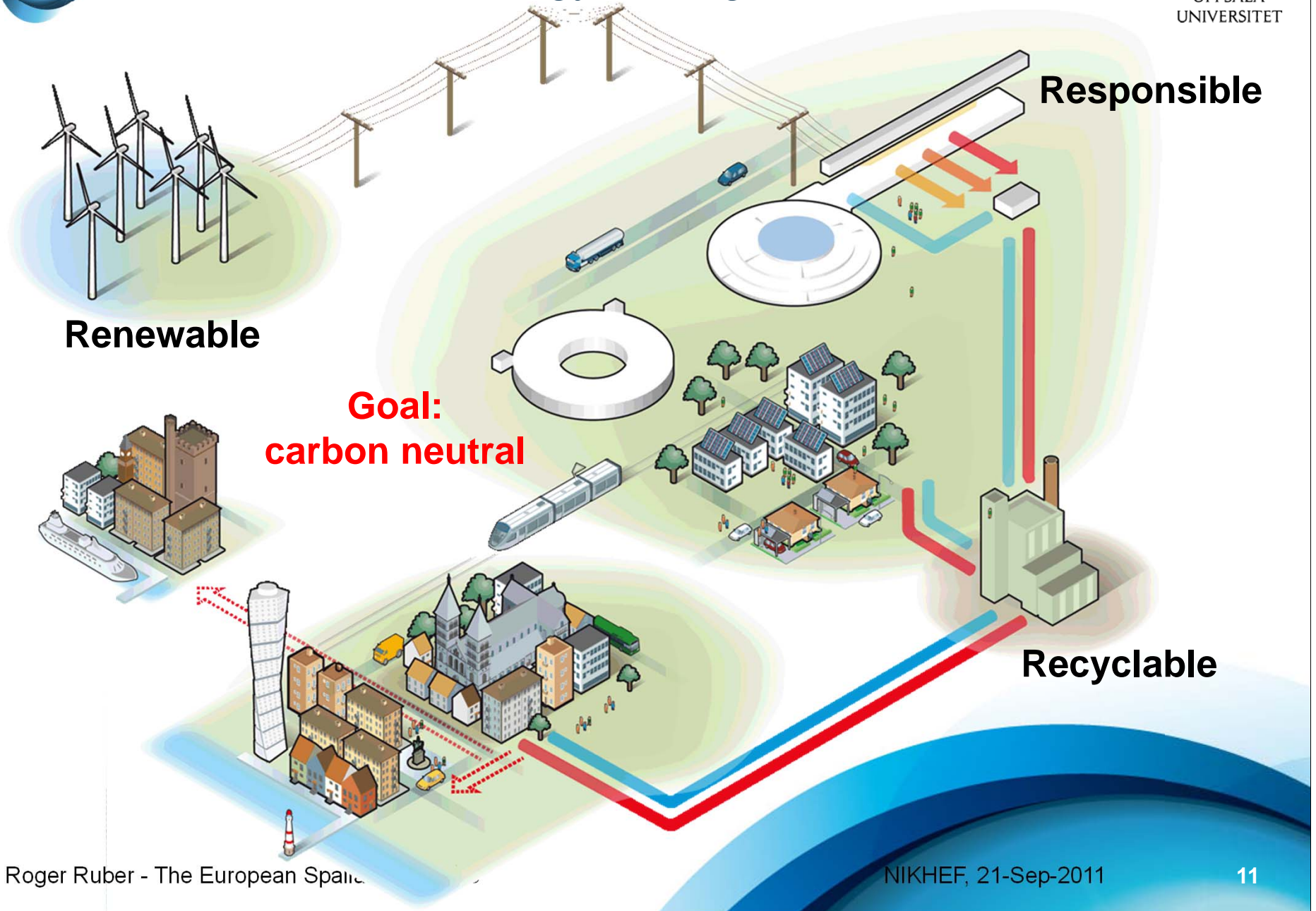
Klystrons

Ion source  
7 GWh/y

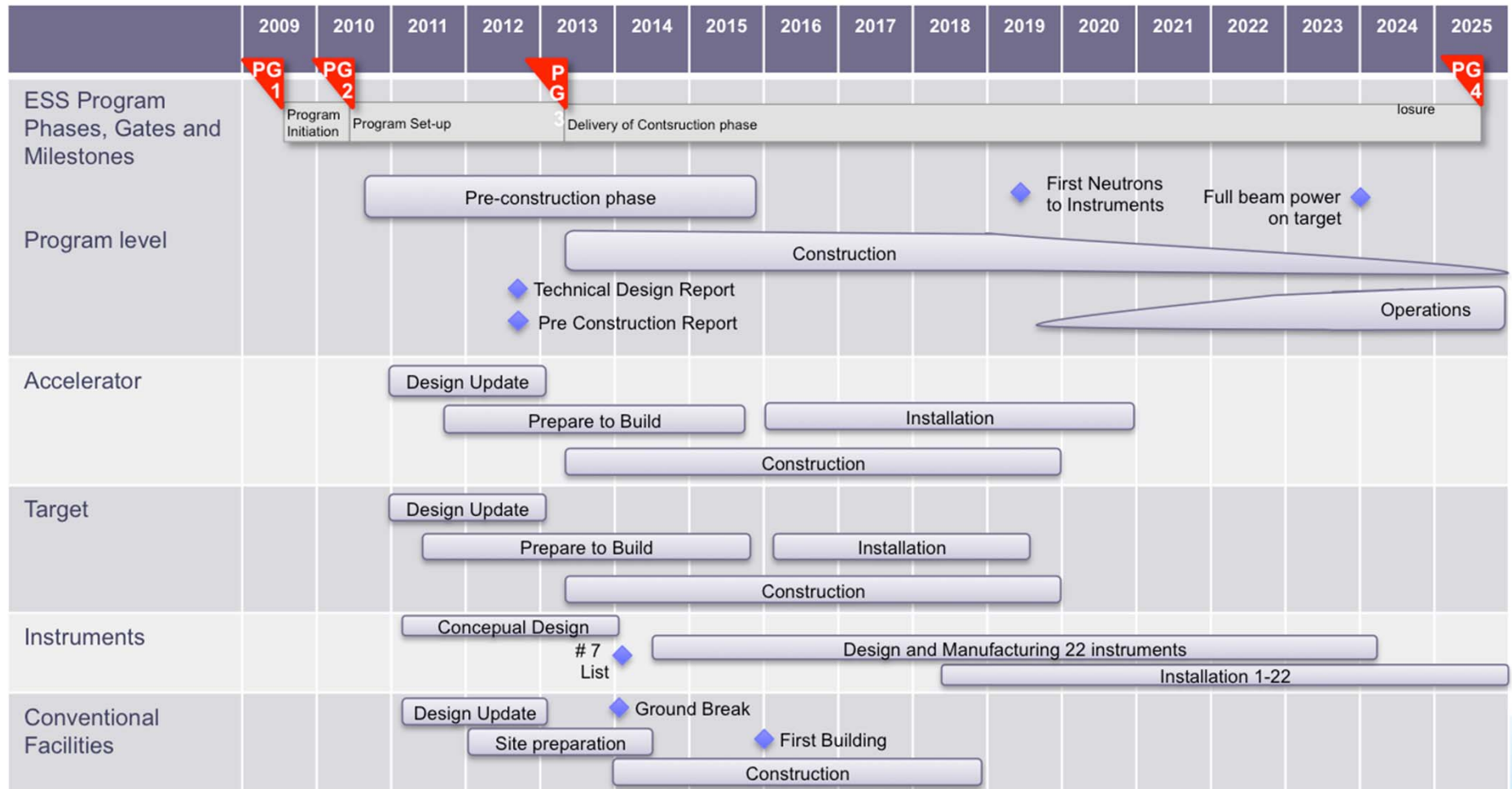
Accelerator  
123 GWh/y







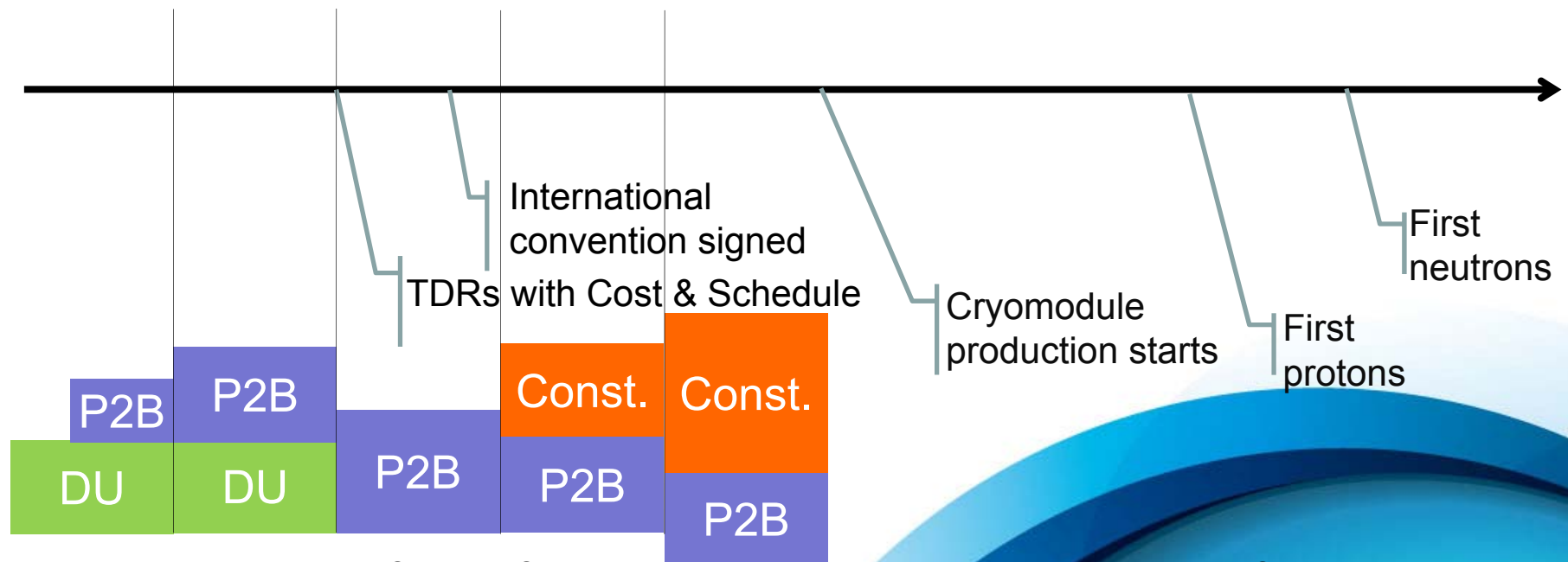
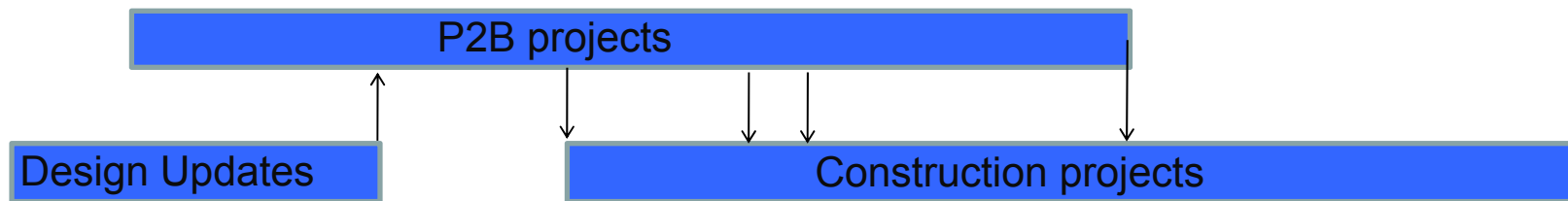
# The Master Schedule



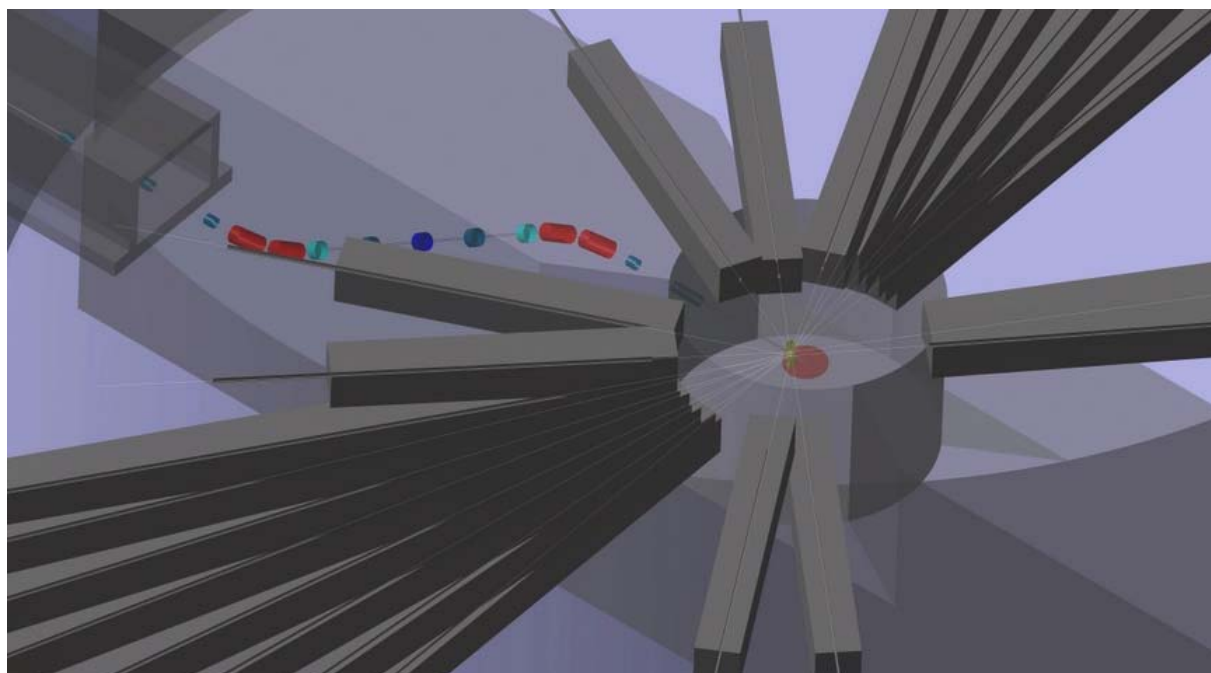


Design Update (DU) and Prepare-to-Build (P2B) provide

- 1) Prototyping &
  - 2) Engineering Design Reports,
- in smooth transitions from design to construction.

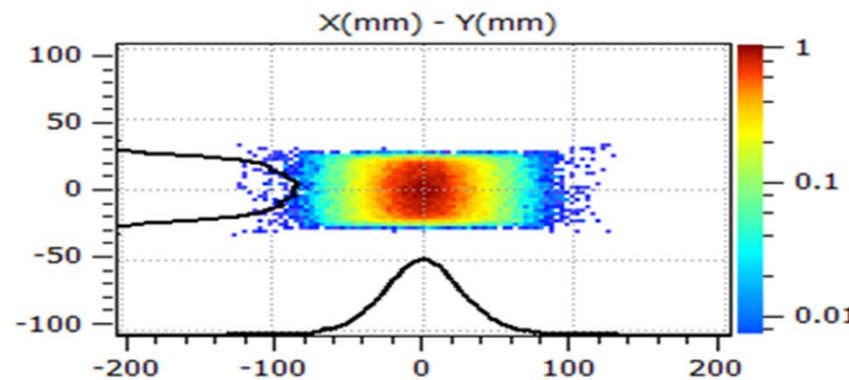
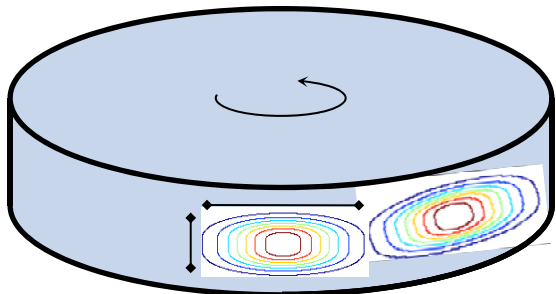
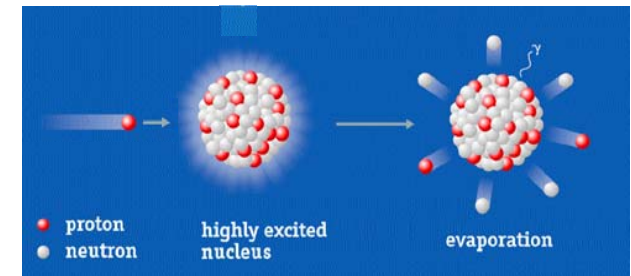
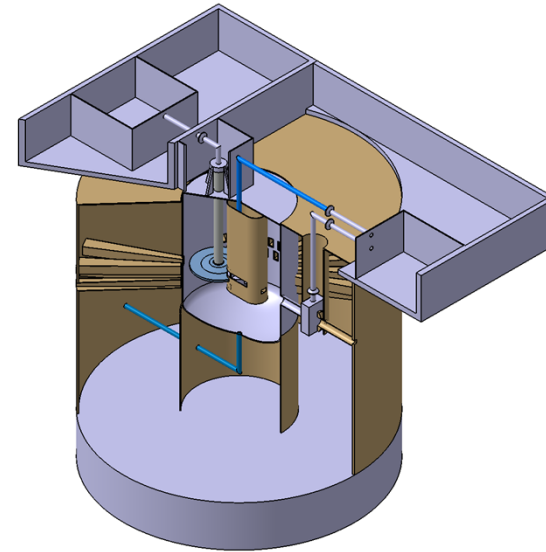


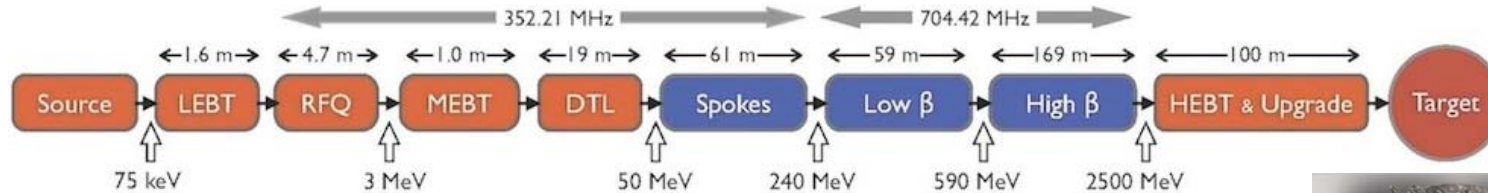
- 22 scientific beam lines and instruments planned
- not all available on day one
- moderator above and below target



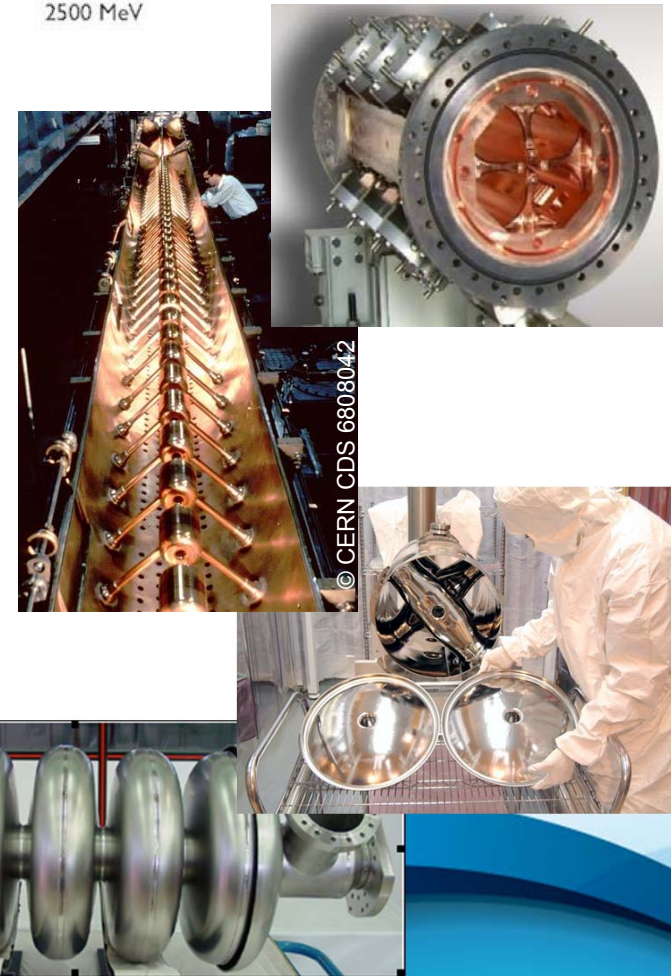
# The Target

- rotating tungsten disk
- gas helium cooled
- life time depends upon
  - maximum peak current density
  - intensity gradient
  - extent of tails
- flatten beam profile with octupoles  
(reduces peak current with 60%)

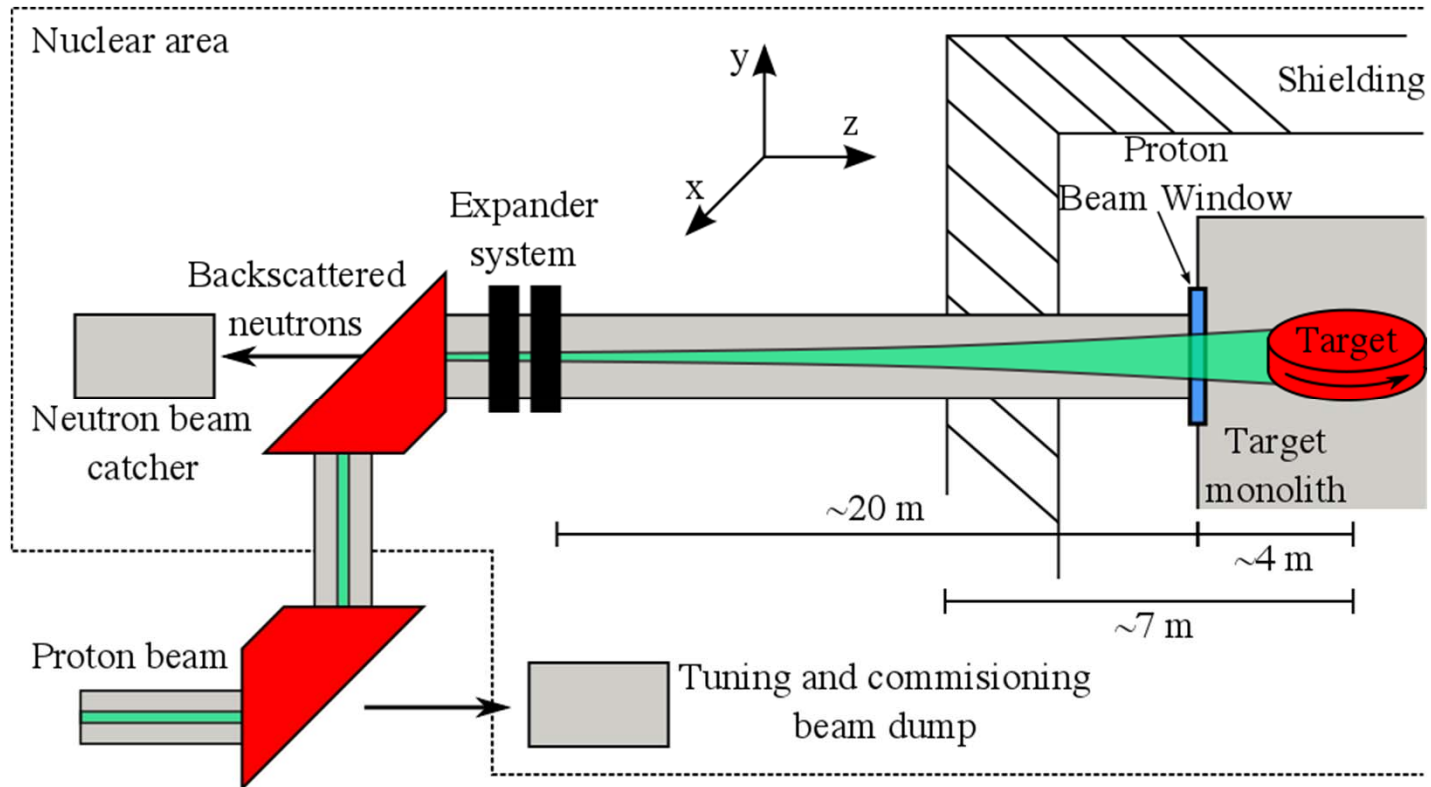




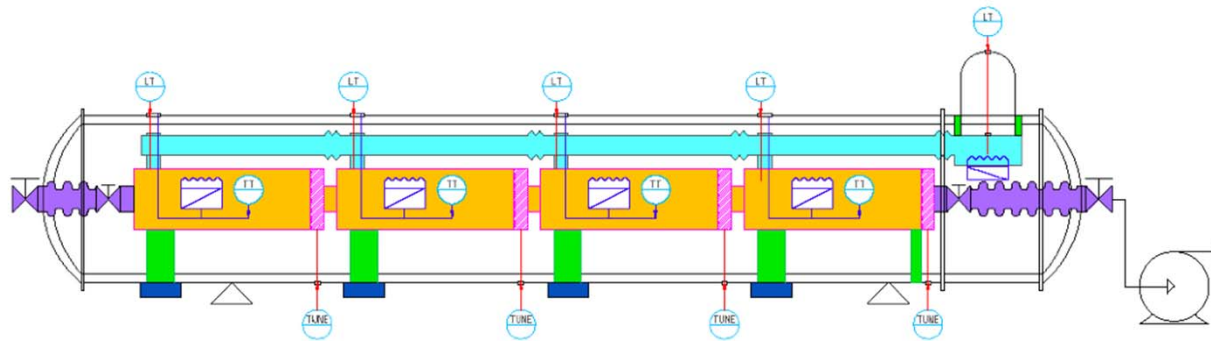
- single pass linear proton accelerator
- normal conducting (room temperature)
  - electron cyclotron resonance (ECR) source
  - radio-frequency quadrupole (RFQ)
  - drift tube linac
- superconducting (liquid helium temperature)
  - double spoke resonators (DSR)
  - elliptical cavities





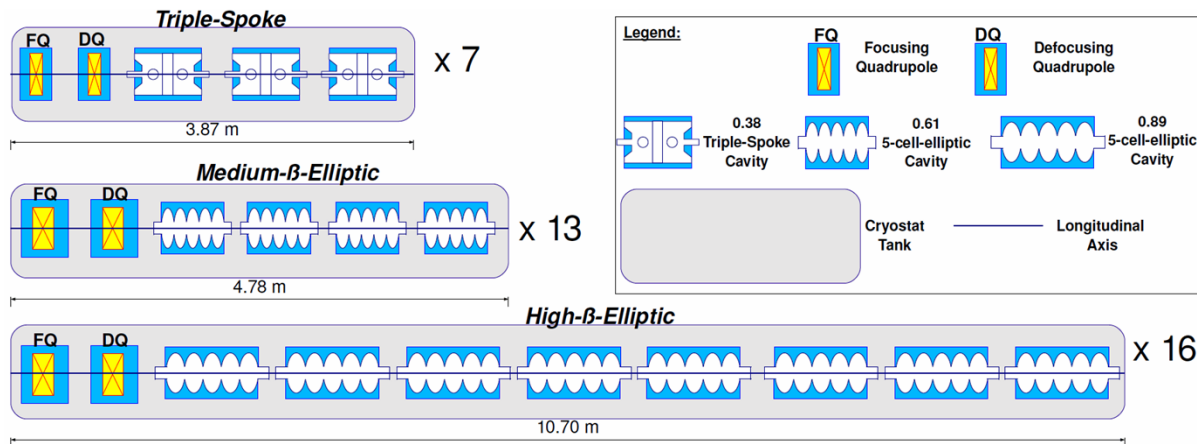


- rise by several meters (-10 to +1.6m)
- backscattered neutrons → radioactive area



## SPL/ESS

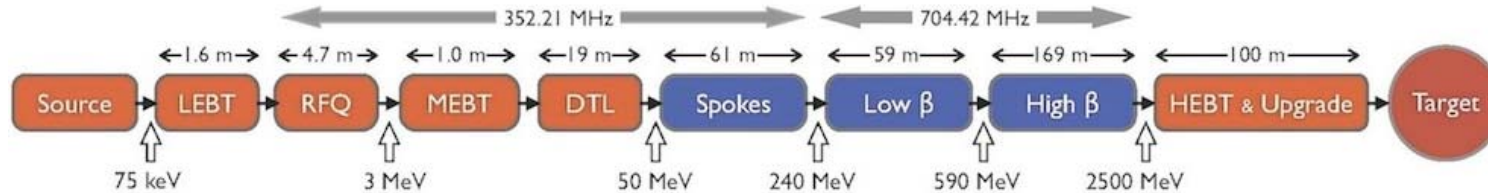
A “half” cryomodule is being built & will be tested at SM18 in collaboration with CERN.



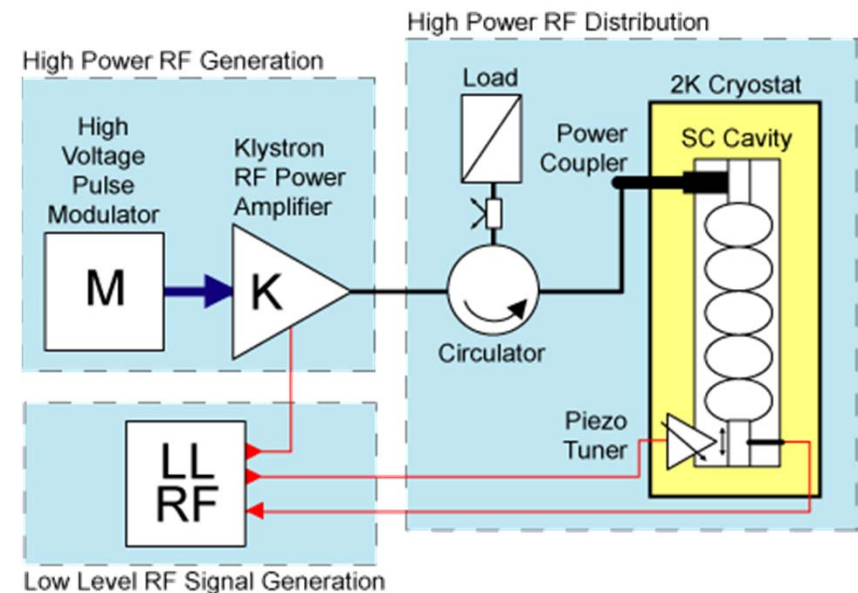
## “2010 BASELINE”

assumed continuous elliptical cryomod, as shown at LEFT.

W. Hees, ESS, V. Parma, CERN & G. Devanz, CEA



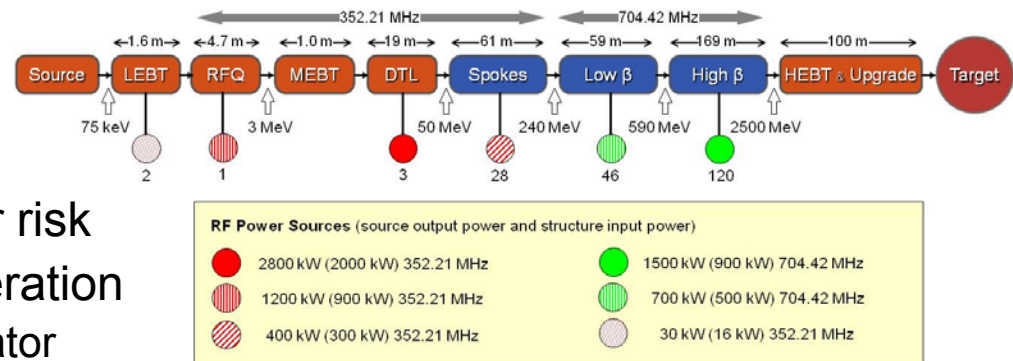
- 200 cavities (352 + 704 MHz)
  - 200 RF systems: modulator, klystron, distribution, controls
  - 5 MW beam  $\rightarrow$  20 MW RF, (losses and LLRF overhead)
- R&D objectives
  - energy efficiency and operational costs reductions
  - produce technical design, with cost estimate, to start tendering



- **Prototype baseline design and acceptance testing of production elements**
  - ion source
  - RFQ, bunchers, DTLs, spokes and elliptical cavities
  - power couplers, tuners, cryo-modules
  - RF system including power sources, distribution and controls (LLRF)

- **200 Accelerating structures and RF distribution points**

- minor fault might create a major risk
- must ensure low beam loss operation
  - to prevent activation of accelerator components
- major part of the accelerator budget
  - must be cost, energy and resource effective for construction & operation



- **Training of future staff**

- prototyping moved to 5 years P2B (in parallel to 2 years ADU)

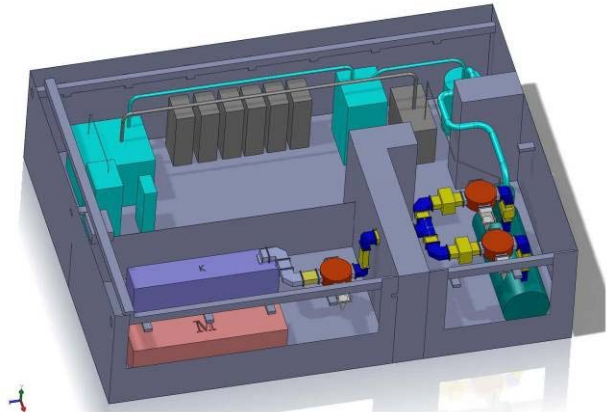


- **Test Facility at Uppsala University**

- prototyping of LLRF and HLRF solutions
- training of students and staff

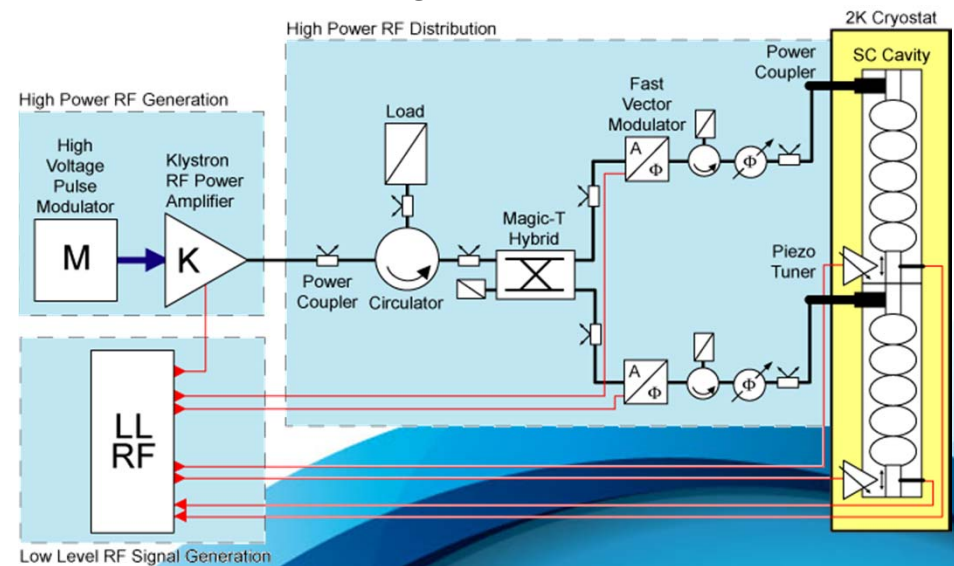
- 4 Years development phase

- 2011 – 2012: design, tendering
- 2013 – 2014: commissioning, R&D RF systems (components & concepts)
- 2015 and beyond: energy efficiency, component testing



- **Hardware:**

- HV pulse modulator
- 704 MHz klystron (1.5 MW)
- RF distribution system
- LLRF system
- 2 SRF elliptical cavities
- helium liquefier



- High losses in the linac
  - Action: Comprehensive studies of beam dynamics (simulations and theory)
- Poor reproducibility in cavity performance
  - Action: Quality control during manufacturing and prototyping of a sufficient large number of cavities
- Limits in cavity performance due to field emission
  - Action: Comprehensive design studies, prototyping and comprehensive tests of cavities and complete cryomodules
- Limits in RF system performance
  - Action: Prototyping, sufficient contingency in design
- Delivery and installation RF system
  - Action: Study alternatives, staging of beam power and energy

- Mechanical

- high precision machining (cavities, vacuum)
- clean assembly, ultra-high vacuum (cavities, beam lines, cryo-lines)
- high quality plumbing (HP gas lines, waveguides)
- high quality welding (vacuum, cryogenics)
- cryostats and cryo-lines
- supports (few kg to many tons)
- alignment and stabilization ( $\mu\text{m}$  and below)
- ceramics (insulation, measurement)

- Electrical & electronics

- electro-magnets
- controls, data acquisition (slow, fast)
- cables, connectors, feed-throughs
- timing and synchronization (ns and faster)
- power converters
- high voltage pulse modulators
- RF power amplifiers (klystron, IOT, ...)
- RF microwave parts (load, circulator, ...)

- Instrumentation

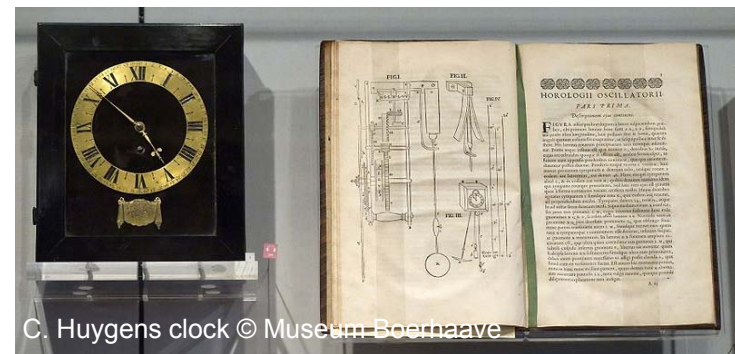
- semi-conductors (detectors, MediPIX)
- scintillating crystals
- optics: mirrors, lenses, cameras
- custom design (mechanics, electronics)

- Software

- controls and supervision (FPGA, PLC, high level, GUI)
- 3D modelling (B, RF: static, time and frequency domains)

- Others

- Energy efficiency
- Thermo-dynamics & acoustics
  - to minimize vibrations



C. Huygens clock © Museum Boerhaave

- Many broad possibilities for industry
  - in Europe and world wide
- There is a large synergy between projects
  - industry can use competences gained in one project towards the next project
  - but it can take years to develop something
- Important to understand your customer,
  - treat the institutes/universities as your friend
  - good quality and trust
- Research can be a business,
  - but researchers are not a businesspersons,  
please keep them happy!

