ESS og MAX-IV, neutron-instrumentering

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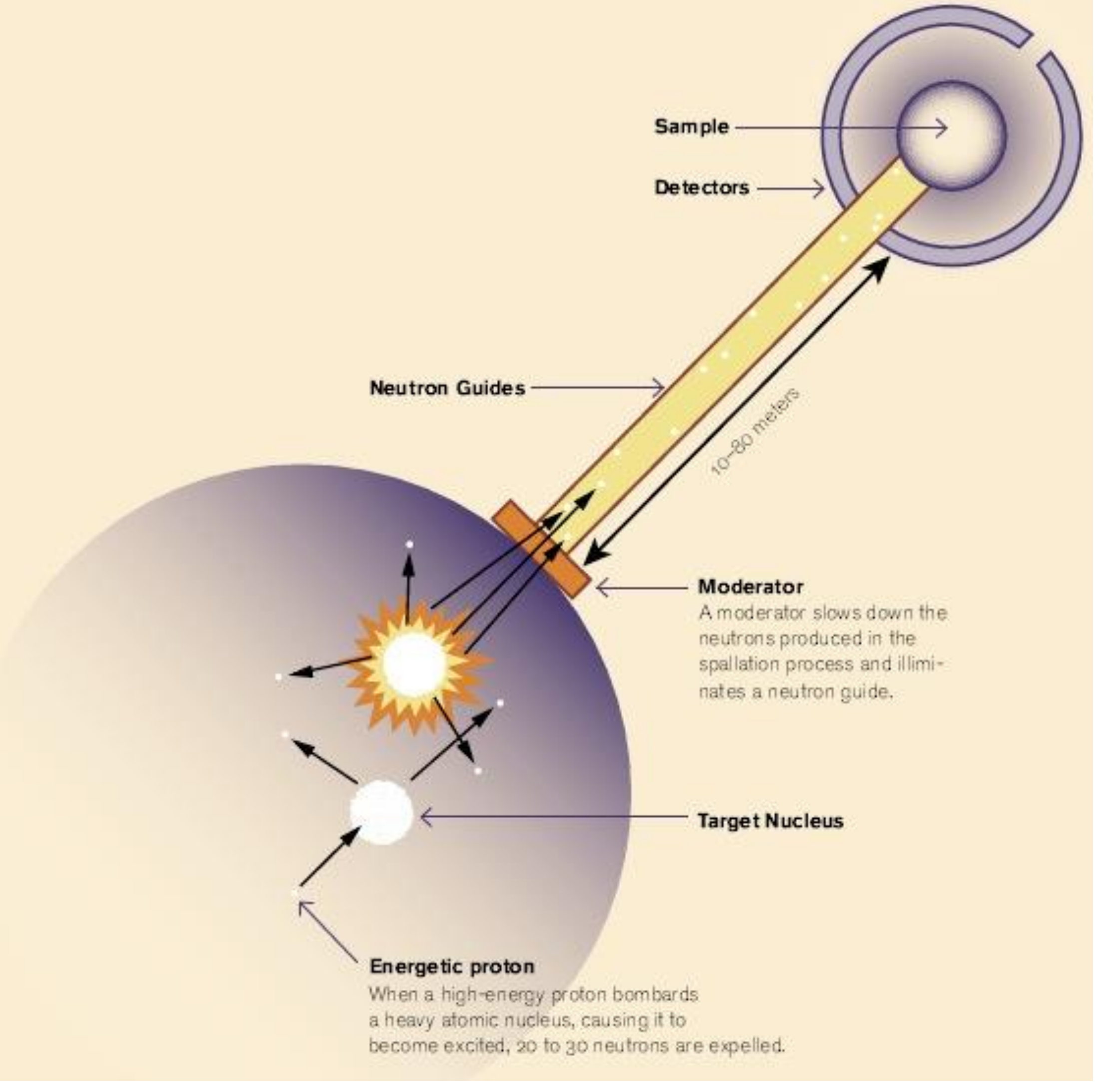

Neutroner - der kan bruges til noget...

1. **Det store overblik**
   - ESS og MAX-V
   - Røntgen vs. Neutroner
   - Lidt mere i dybden med ESS

2. **Moderne neutron-instrumentering**
   - At køle neutroner - til relevant bølgelængde / energi
   - Transport over afstand
   - Tilpassede beams til det enkelte eksperiment

3. **ESS som projekt**

ESS og MAX-IV I Lund, stråling via partikel-acceleration:

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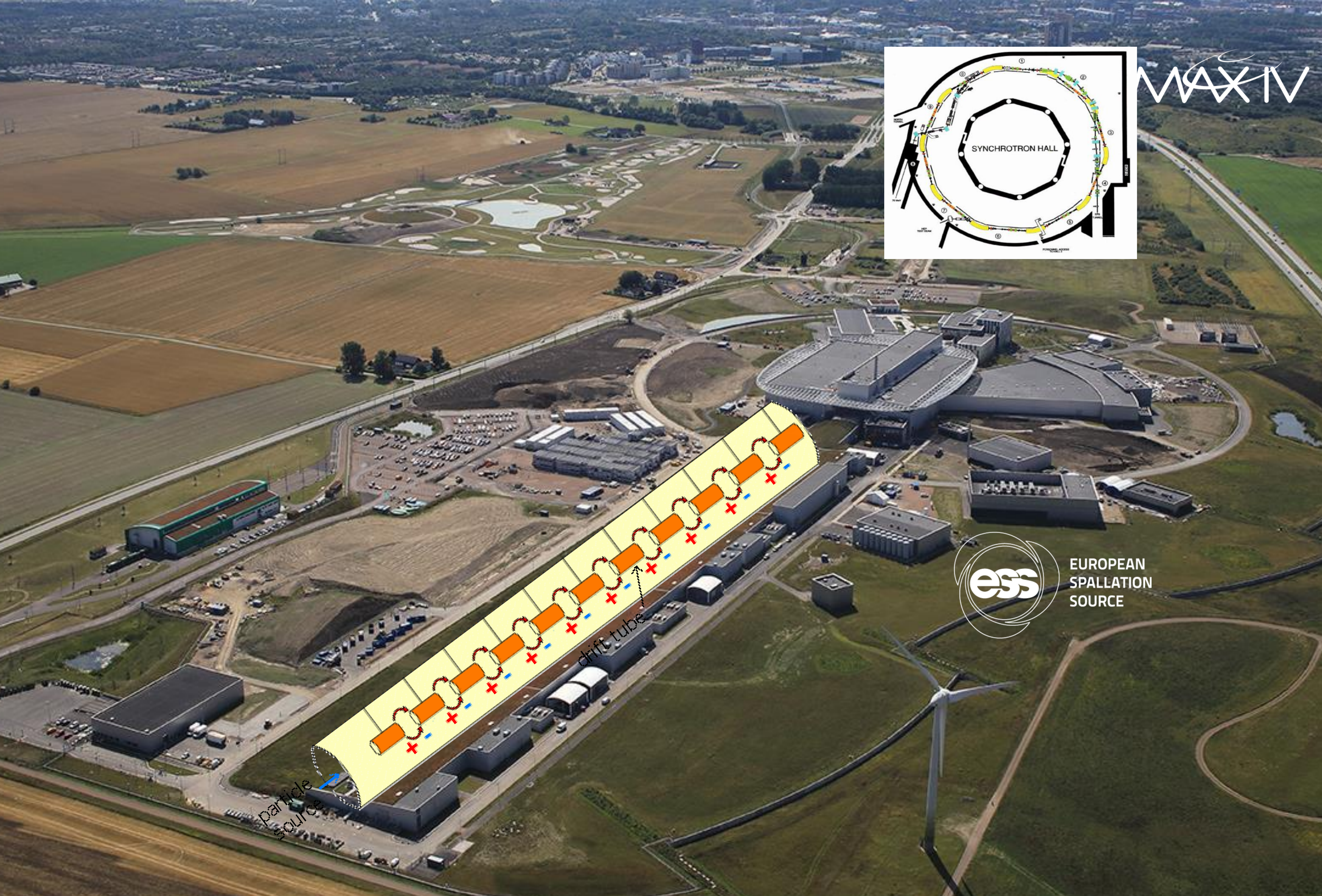
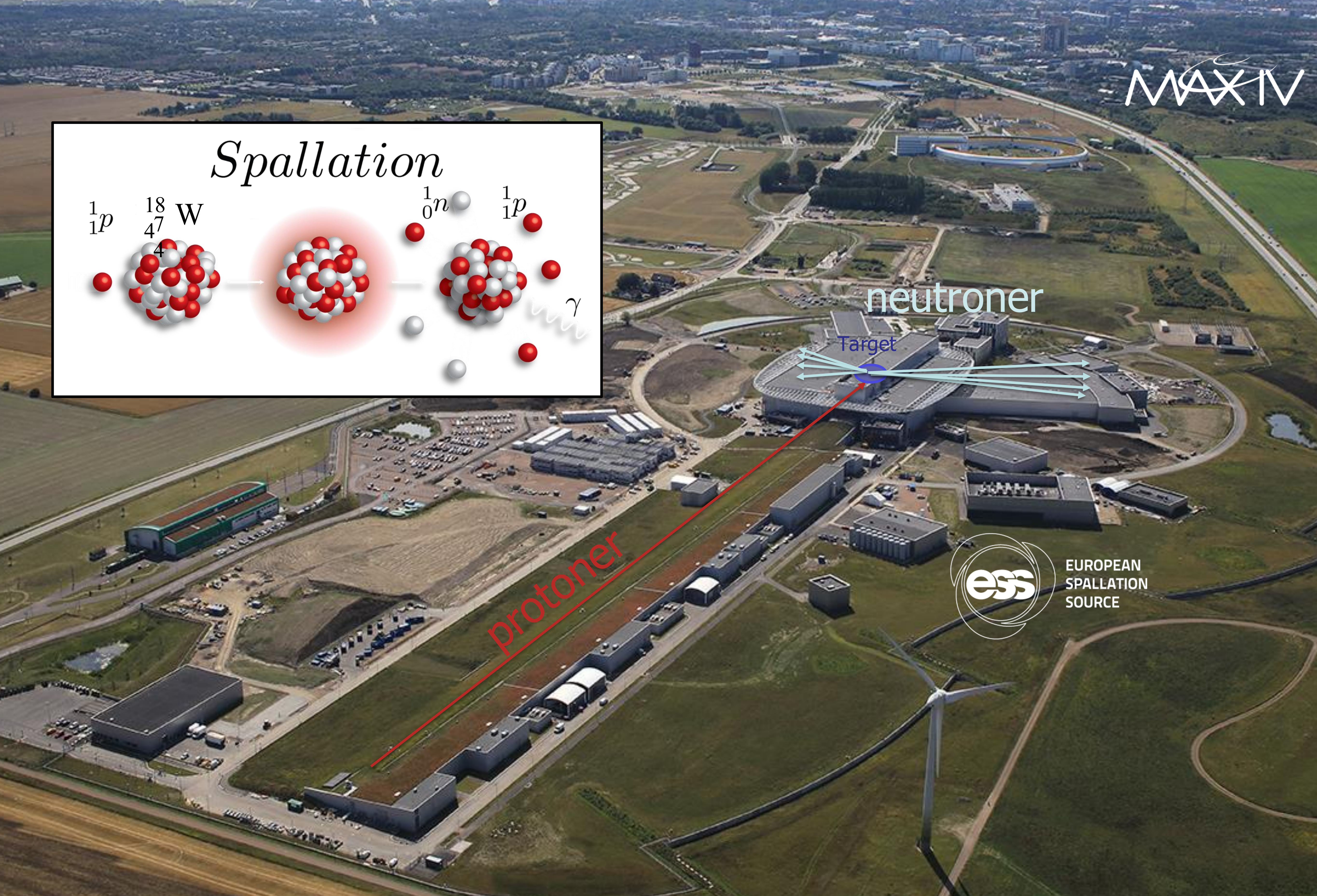
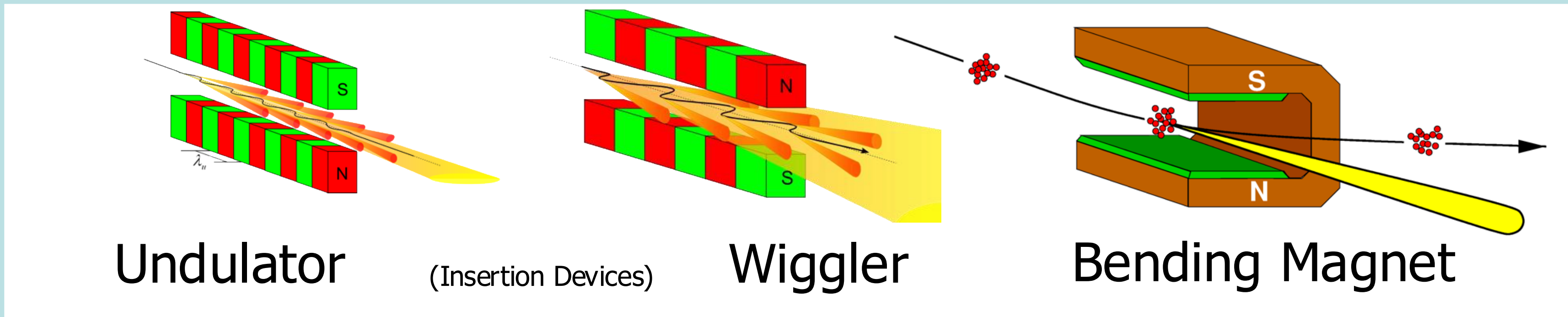


ESS og MAX-IV I Lund, stråling via partikel-acceleration:



ESS og MAX-IV I Lund, stråling via partikel-acceleration:



Både neutroner og X-rays vekselvirker med atomer

- X-rays "ser" elektronskyen rundt om atomkernen - højere atomnummer, mere spredning
- Neutroner "ser" derimod kernen - ingen simpel sammenhæng med atomnummer

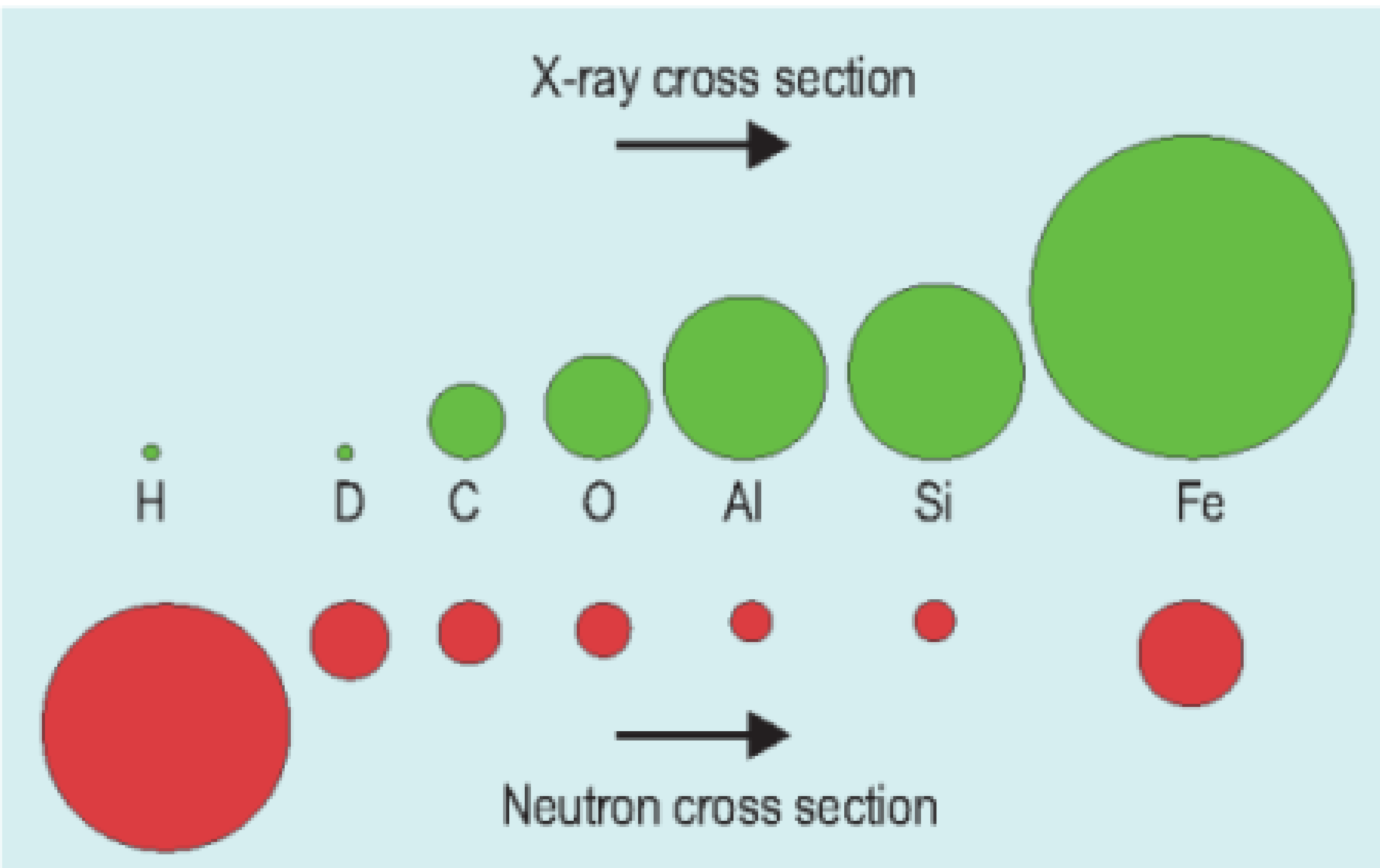
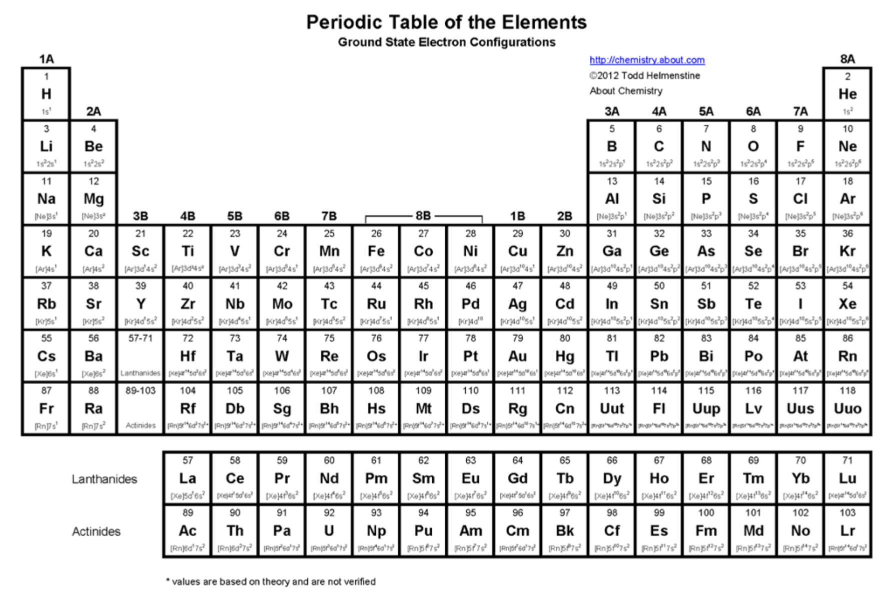
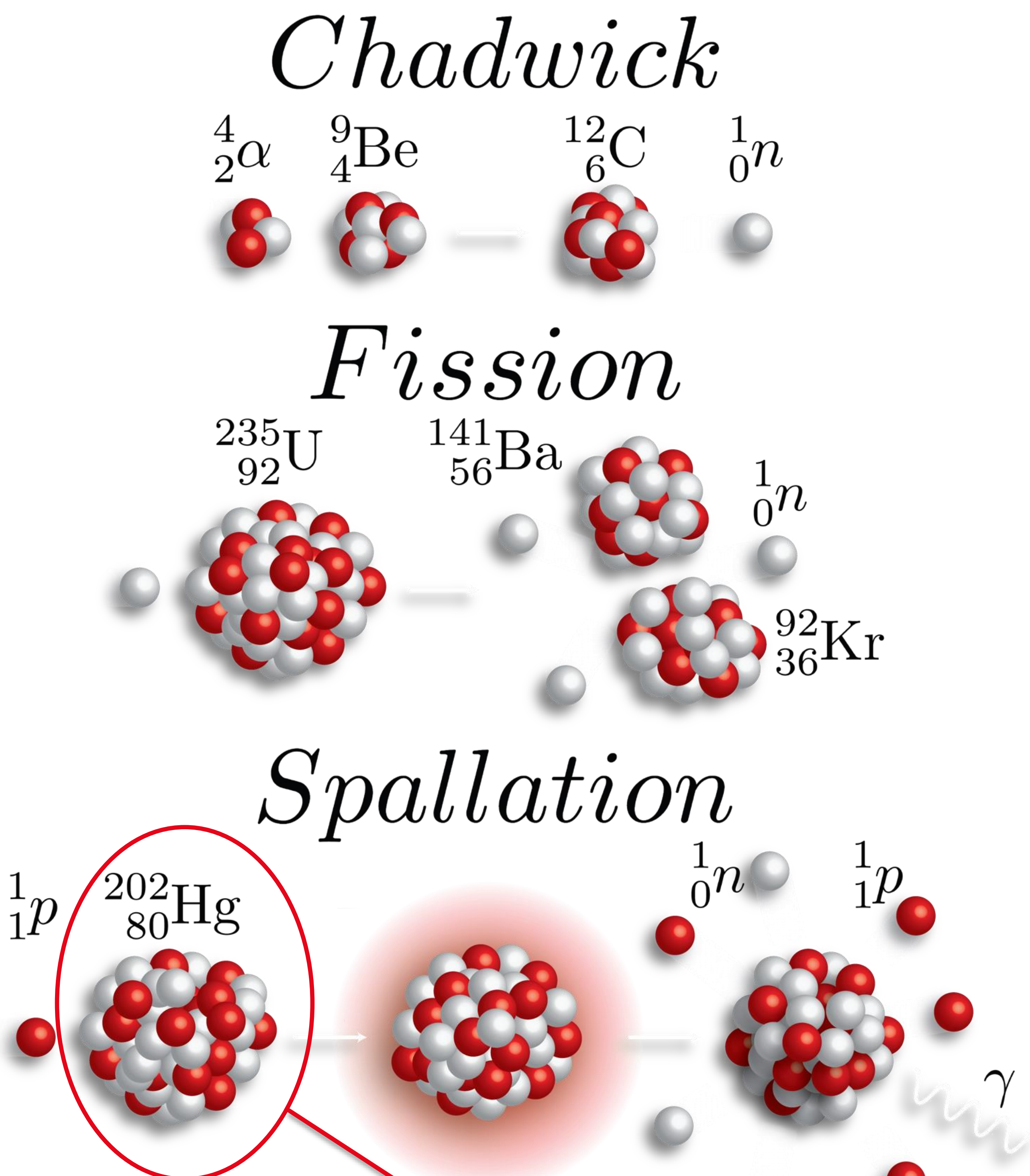


Fig. 2. Neutron and x-ray scattering cross-sections compared. Note that neutrons penetrate through Al much better than x rays do, yet are strongly scattered by hydrogen.



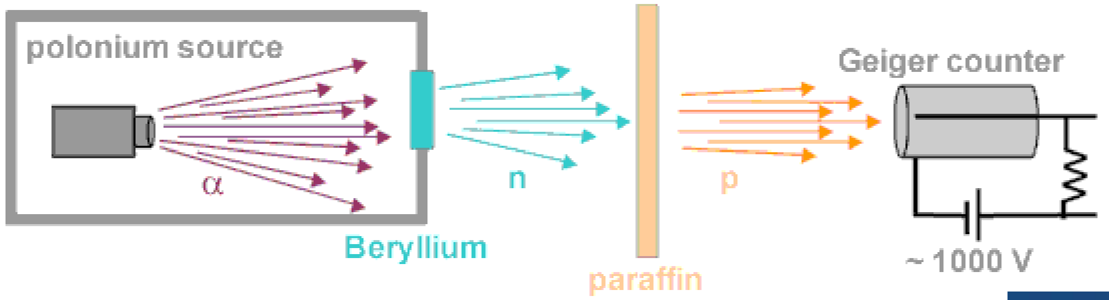
Herfra handler det mest om neutroner :-)

At producere neutroner…

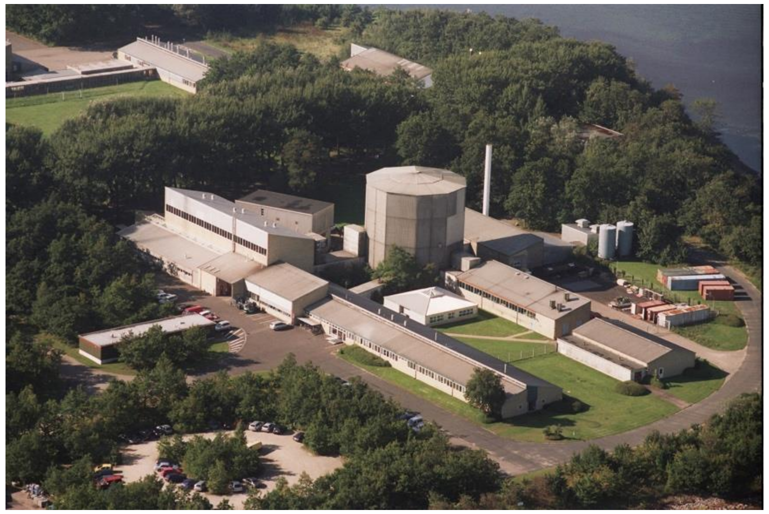


Figur: Mads Ry Vogel Jørgensen, AU

Chadwick's eksperiment / α på Be



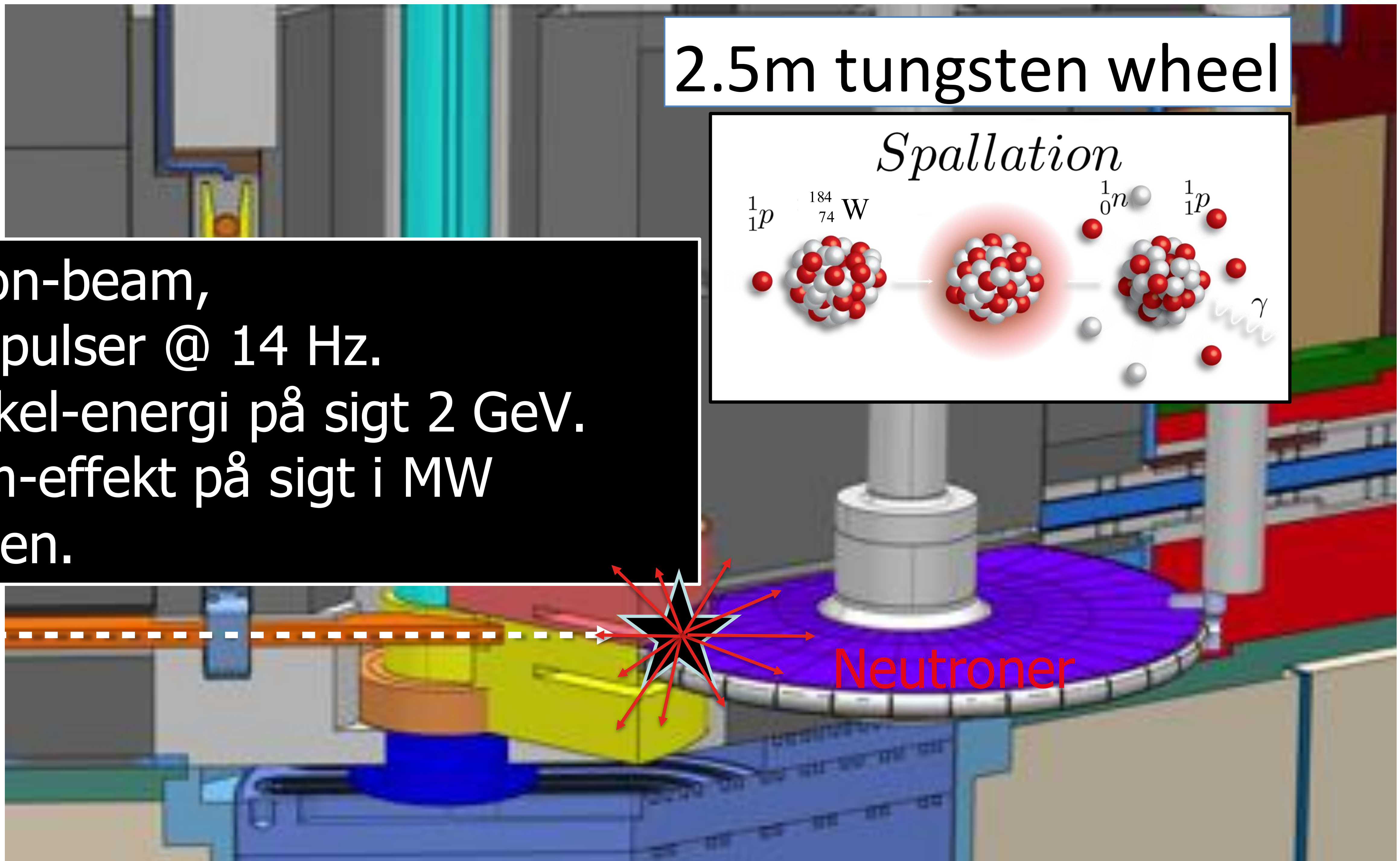
RISØ's DR 3 reaktor



SNS, Oak Ridge Tennessee

På ESS bruger vi W

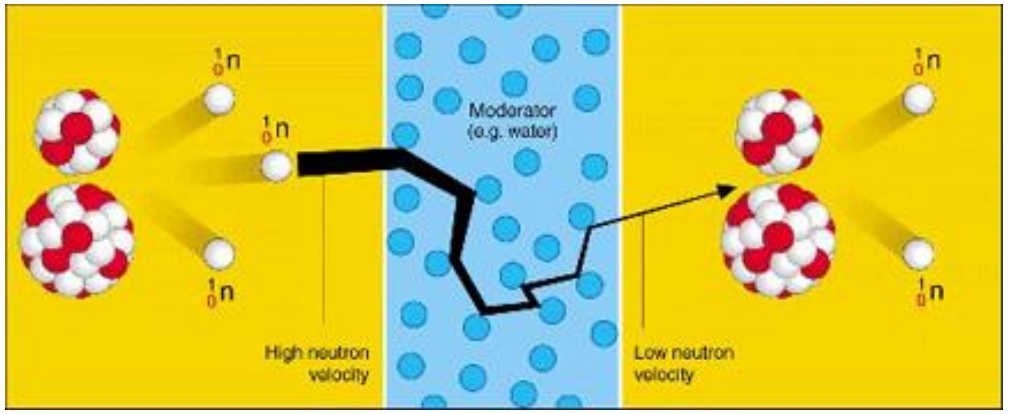
ESS target



Proton-beam,
3ms pulser @ 14 Hz.
Partikel-energi på sigt 2 GeV.
Beam-effekt på sigt i MW klassen.

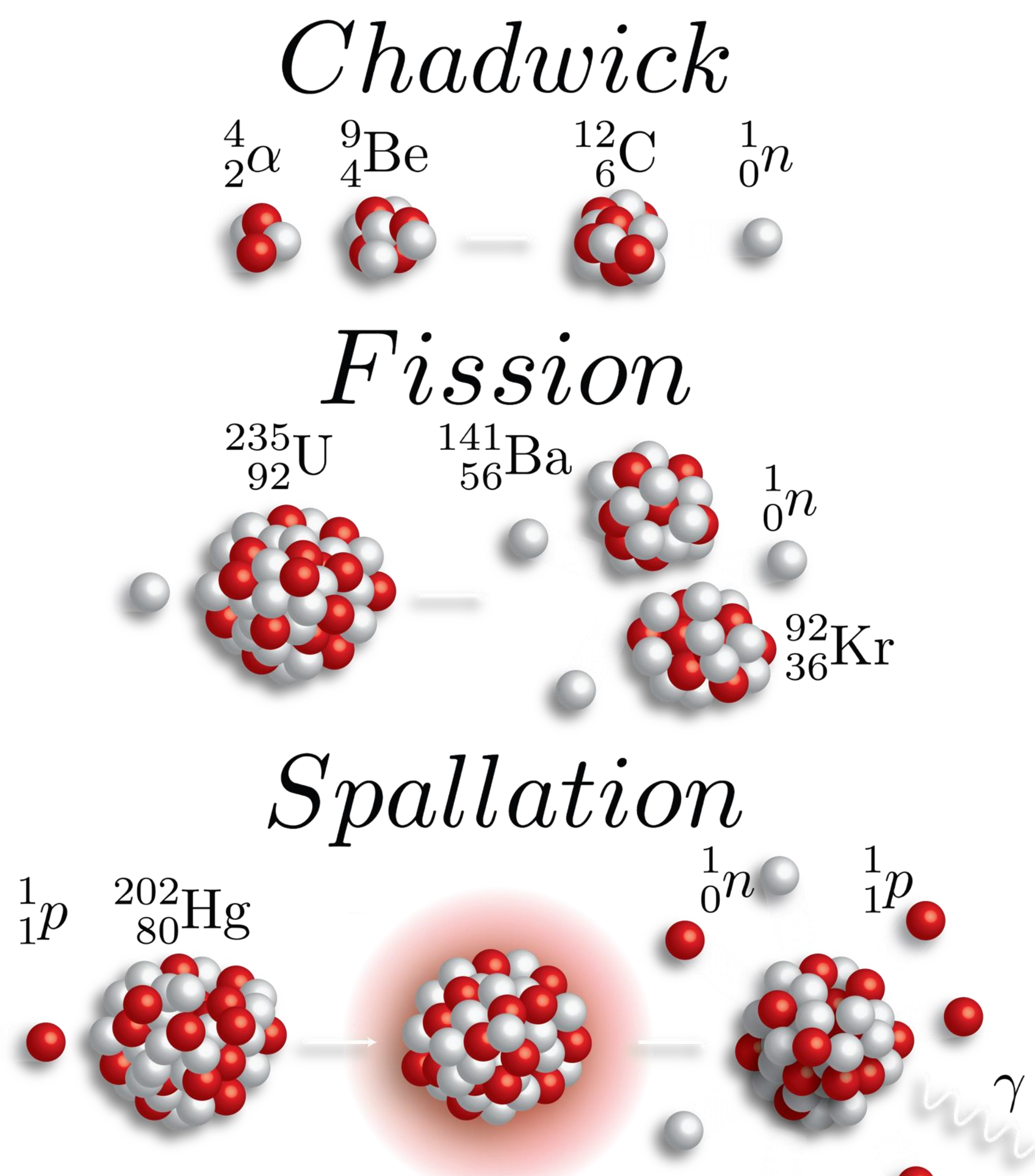
Neutron-moderation

- Energi-udgangspunktet i såvel reaktorer og spallationskilder er "lige højt nok"
- - Målet er bølgelængder i Å-området / energier i meV (**lille** m, ikke store M)



- I neutronspredning taler vi om *termiske* og *kolde* neutroner, hhv. svarende til (f.eks.) medierne H_2O ved stuetemperatur og H(l) eller CH_4 ~ 20K
- Populært *køler* (modererer) vi neutronerne til passende energi ved "random walk" i "en spand kold vand" eller "flaske flydende brint".
- Resultat: Neutroner med ønskede egenskaber stråles ud i ~ 4π rumvinkel

At producere neutroner...



Figur: Mads Ry Vogel Jørgensen, AU

Nuclear process	Example	Neutron yield	Heat release (MeV/n)
d-t in solid target	400 keV d on t in Ti	4×10^{-5} n/d	10,000
Deuteron stripping	40 MeV d on liquid Li	7×10^{-2} n/d	3500
Nuclear photo effect from e⁻ bremsstrahlung	100 MeV e⁻ on ^{238}U	5×10^{-2} n/e⁻	2000
^{9}Be(d, n)^{10}Be	15 MeV d on Be	1 n/d	1000
^{9}Be(p, n; p, pn)	11 MeV p on Be	5×10^{-3} n/p	2000
Nuclear fission	Fission of ^{235}U by thermal neutrons	1n/fission	180
Spallation	800 MeV p on ^{238}U or Pb	27 n/p or 17 n/p	55 or 30

Accelerators for Neutron Generation and Their Applications

Reviews of Accelerator Science and Technology
Vol. 4 (2011) 219–233

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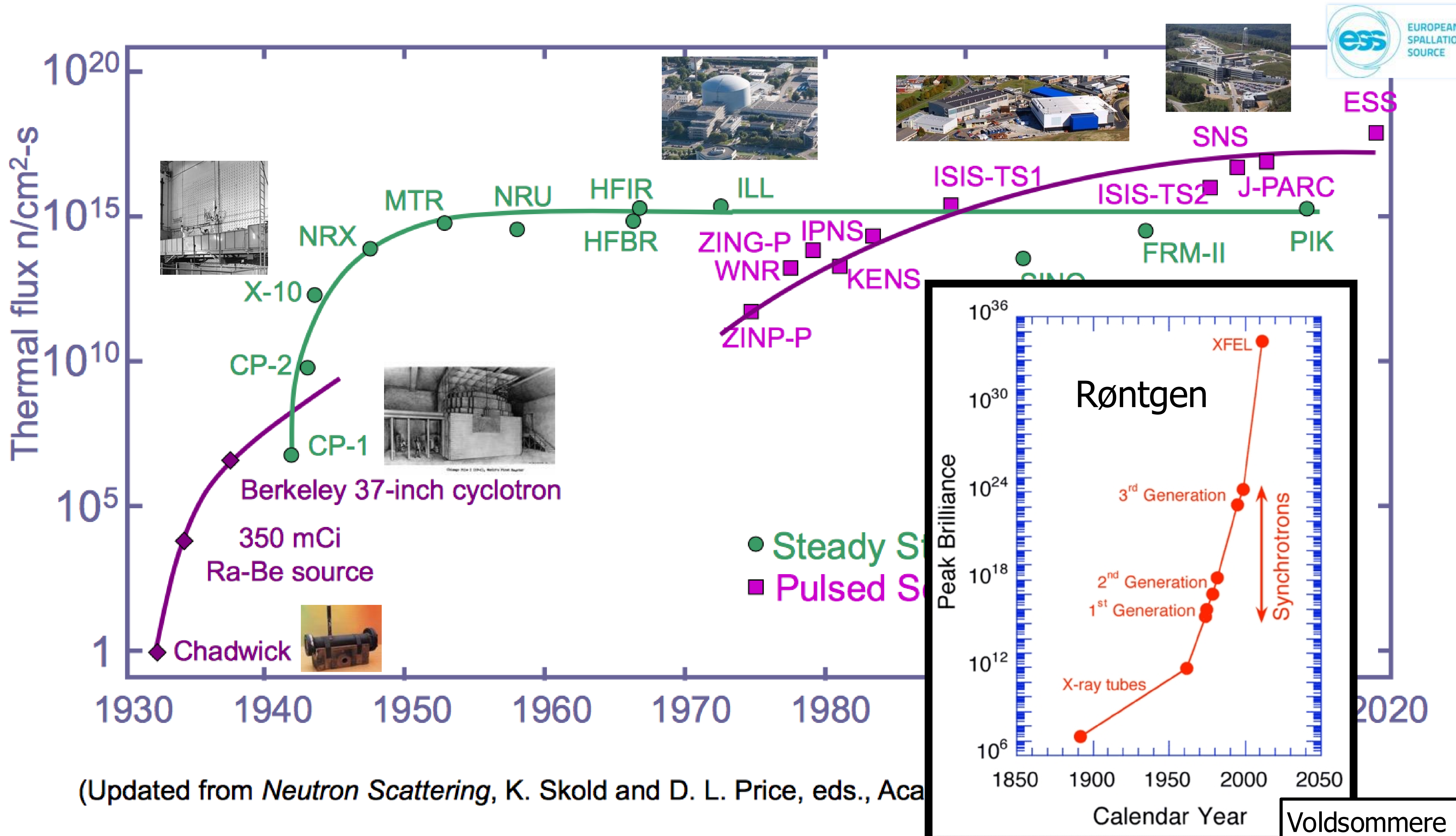
*Fremtiden (50år +) *kan* betyde brug af fusions-reaktorer, men de bruges pt. til andre formål…. ;-)

Performance af neutronkilder

- I enheder af "brugbare neutroner", dvs. instantan brillians (det kommer vi tilbage til hvad er…)



(Updated from *Neutron Scattering*, K. Skold and D. L. Price, eds., Aca

Voldsommere fremskrivning i X-ray land….

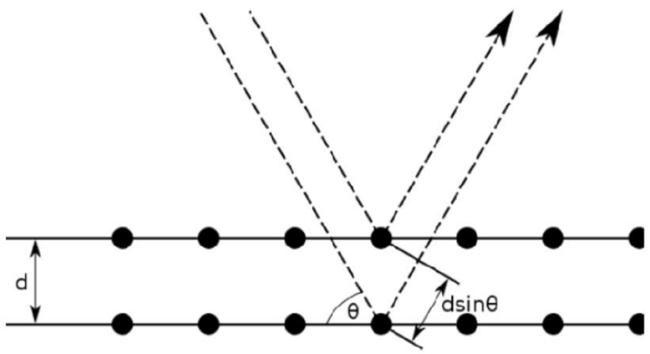
Reaktor vs. spallationskilde:
konstant vs. pulset (typisk)

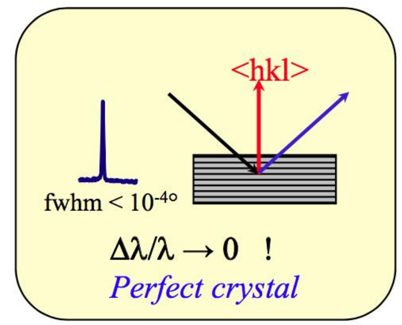
- Jfr. (f.eks.) Braggs lov har vi behov for at vide "hvad bølgelængden er"

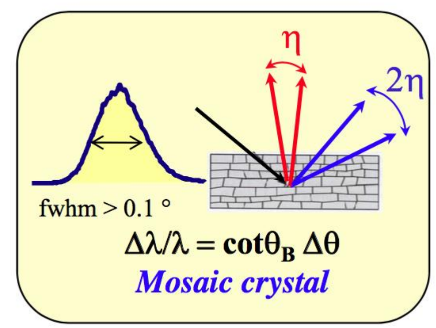
- På reaktorer benytter vi typisk netop Braggs lov til at vælge denne bølgelængde:

Bragg's law:

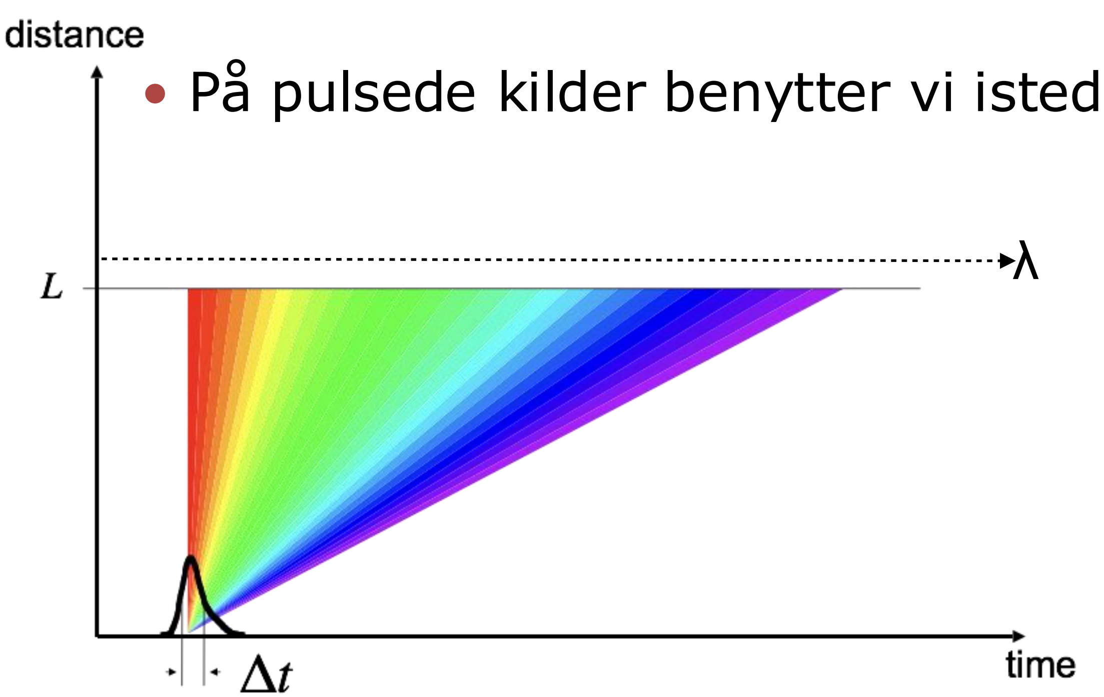
$\lambda = 2d\sin\theta$







- På pulsede kilder benytter vi istedet Time-of-Flight (ToF)



Reaktor vs. spallationskilde:

konstant vs. pulset (typisk)

- Jfr. (f.eks.) Braggs lov har vi behov for at vide "hvad bølgelængden er" når vi måler "afbøjet stråling"

- På reaktorer benytter vi typisk netop Braggs lov til at vælge denne bølgelængde:

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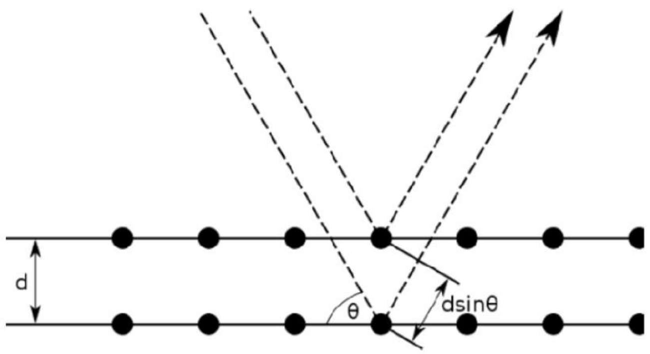
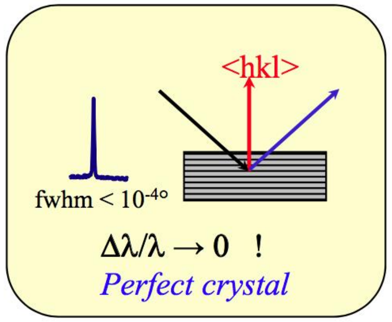
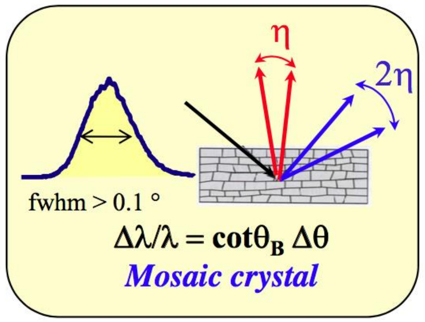
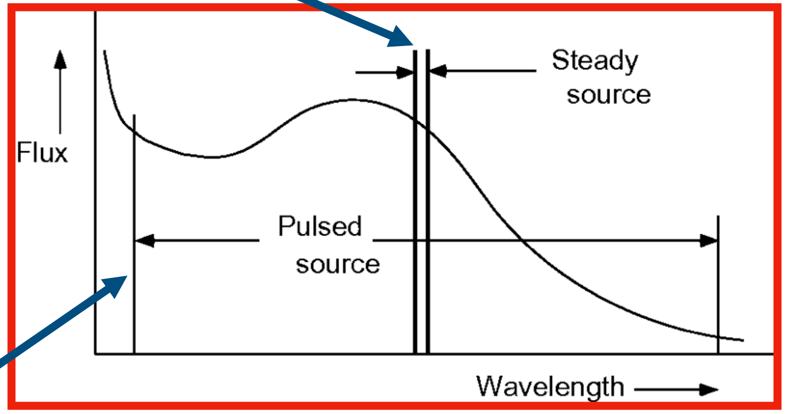


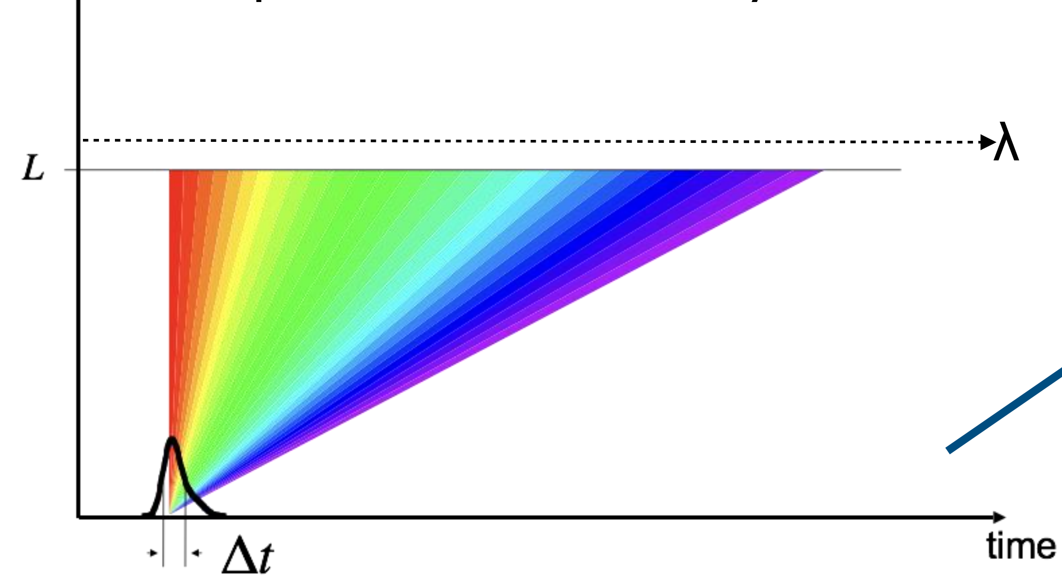




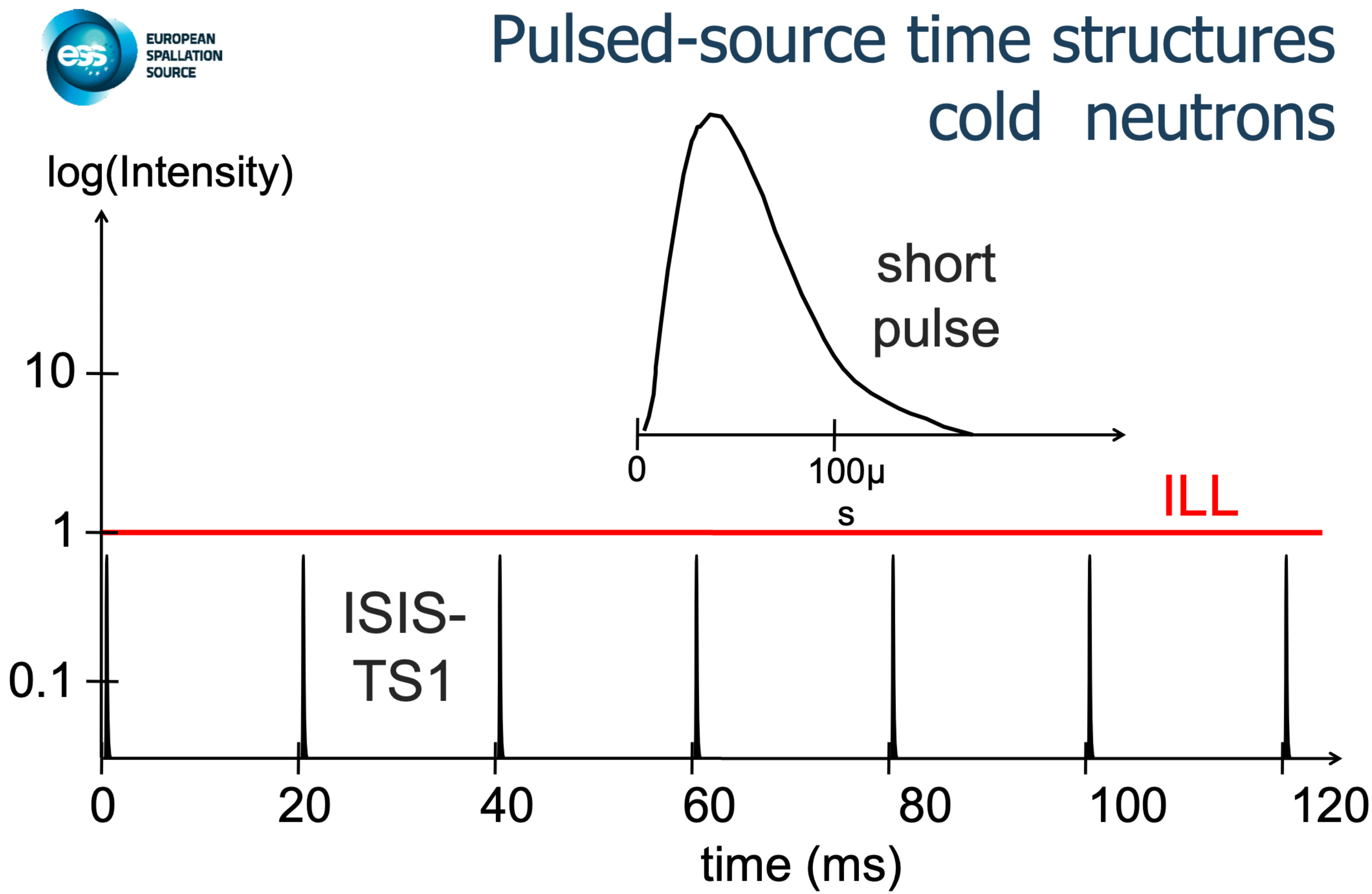


distance

- På pulsede kilder benytter vi istedet Time-of-Flight (ToF)



ILL vs. de pulsede kilder - performance



ILL vs. de pulsede kilder - performance

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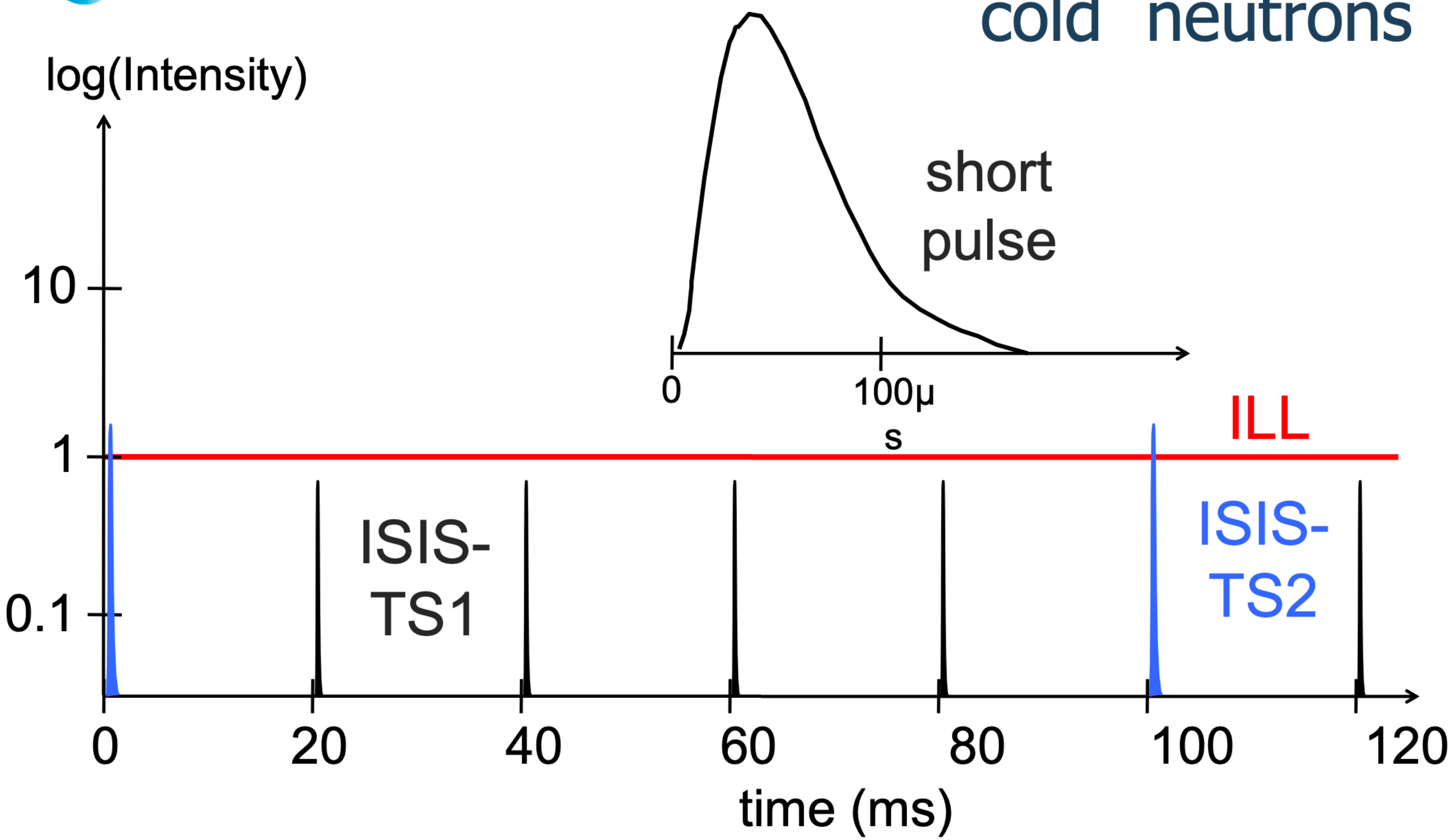
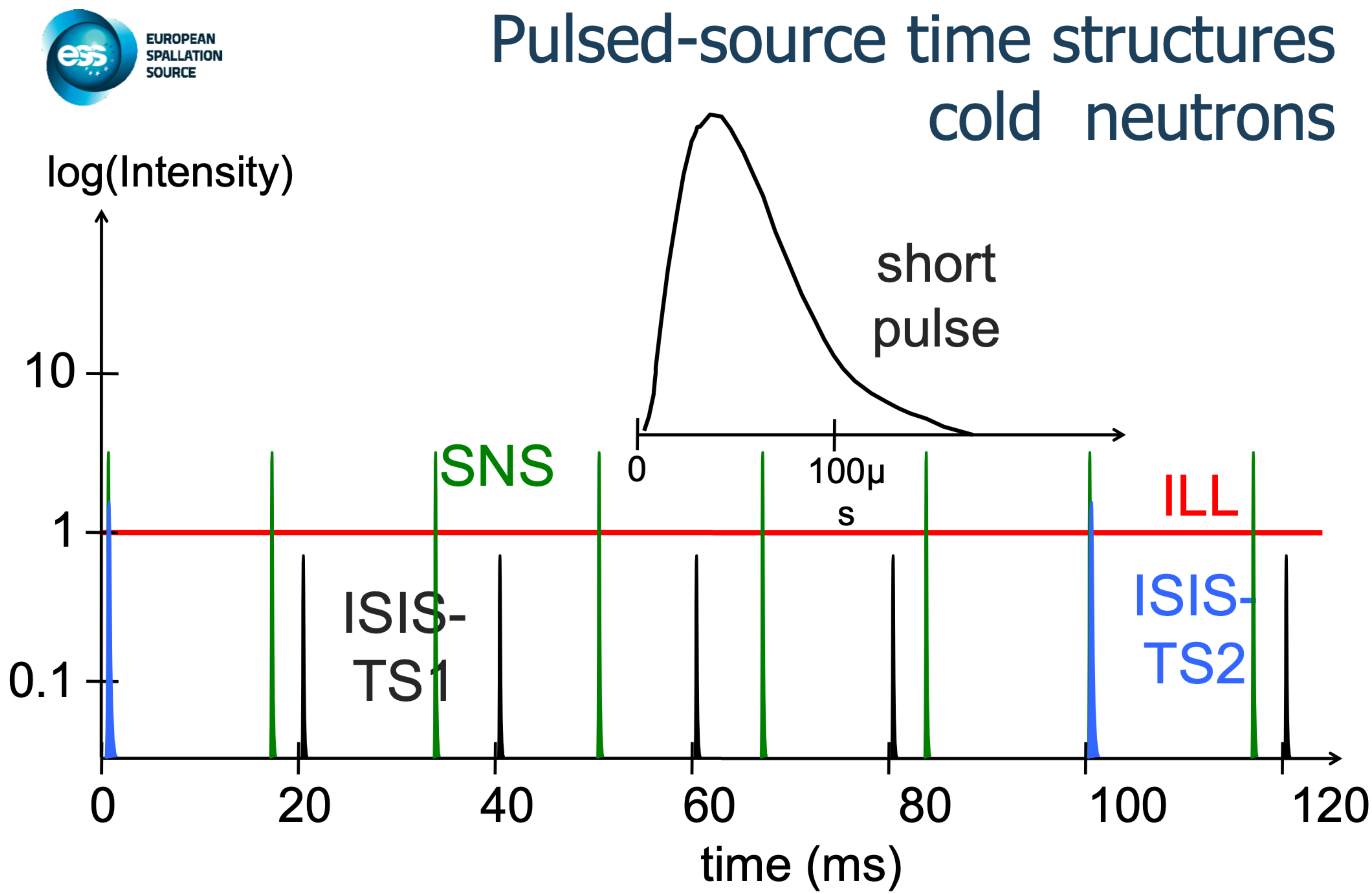
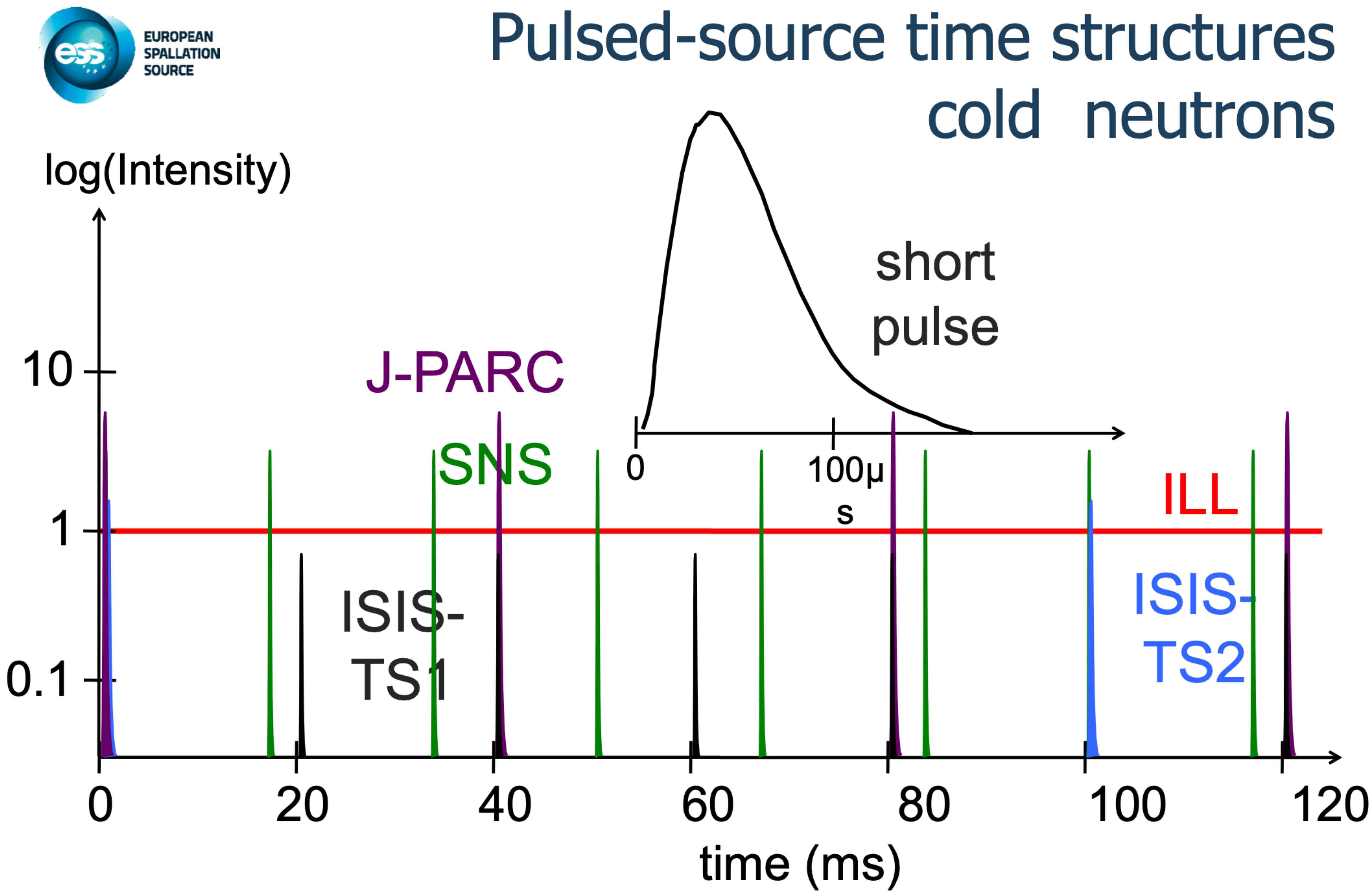
Pulsed-source time structures cold neutrons



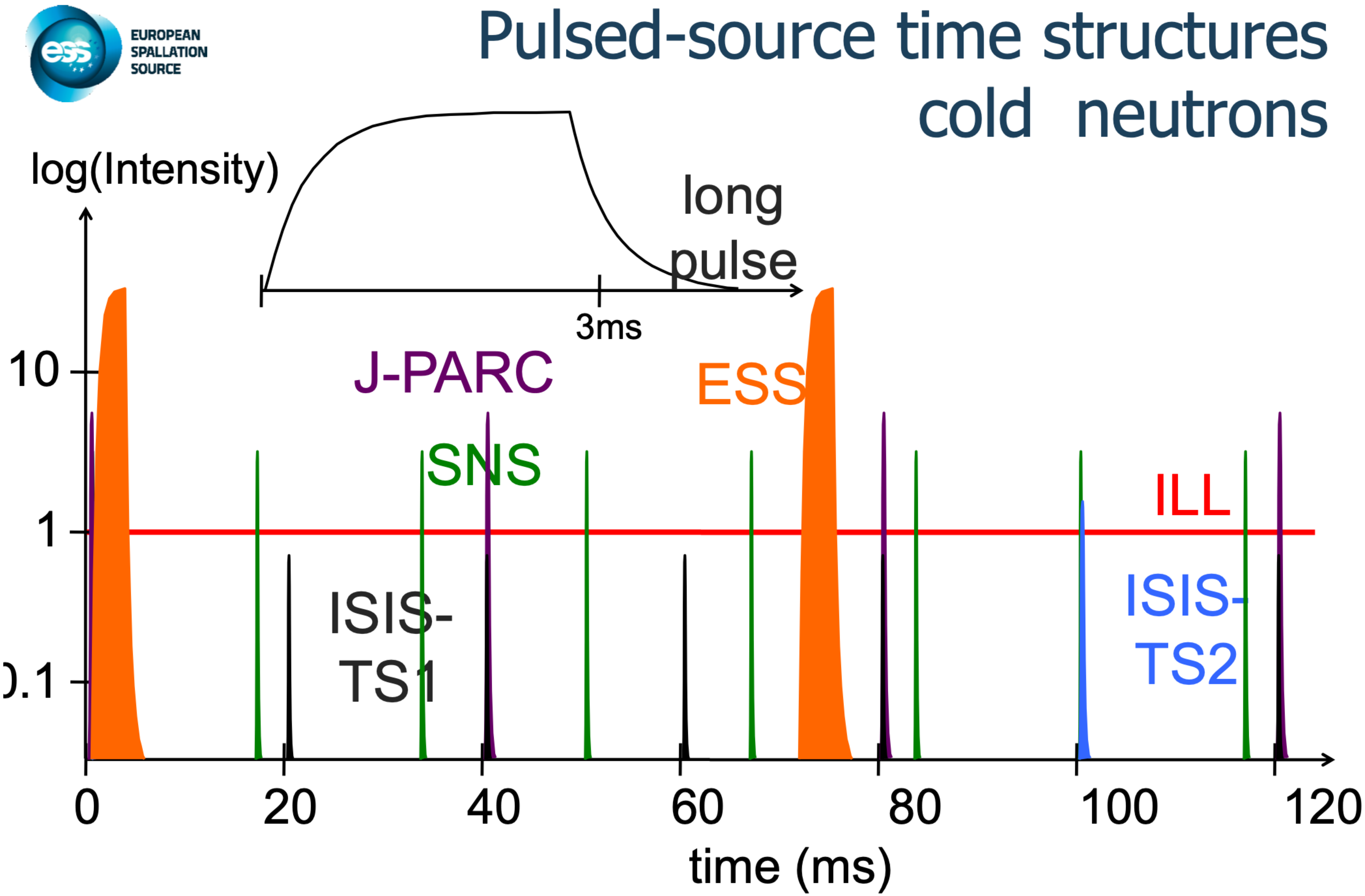
ILL vs. de pulsede kilder - performance



ILL vs. de pulsede kilder - performance



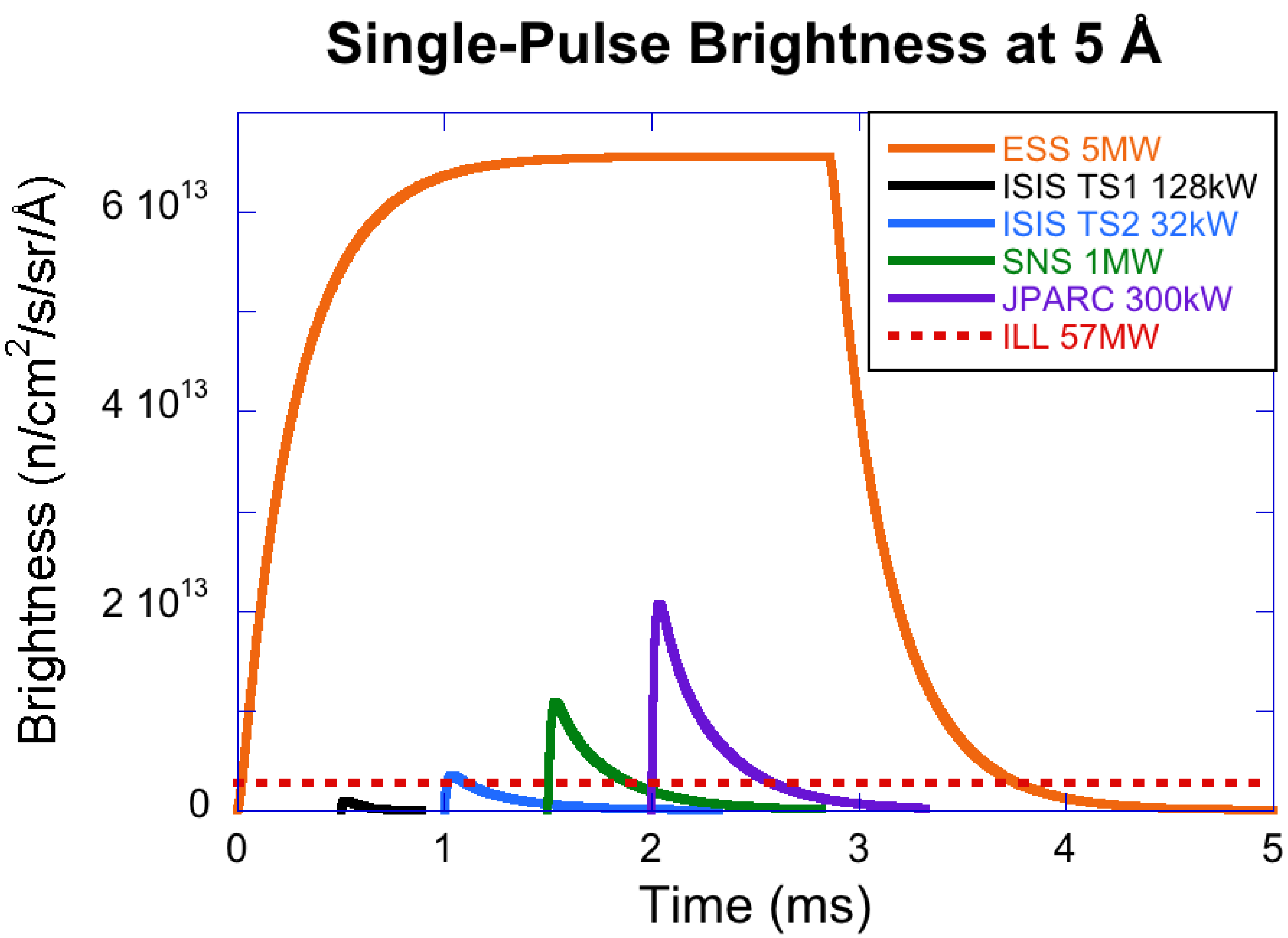
ILL vs. de pulsede kilder - performance



Altså…

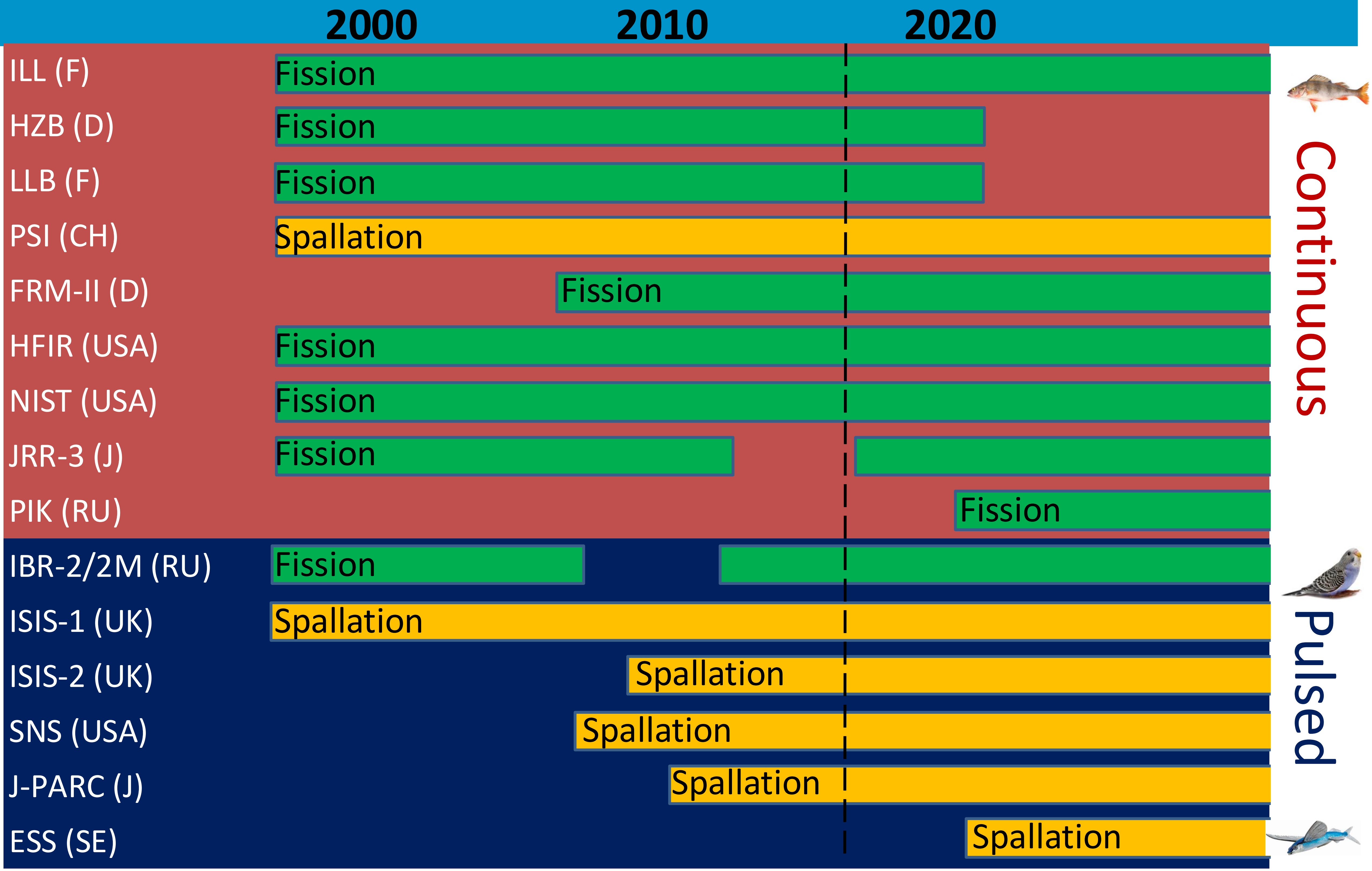


- ESS er hverken en steady-state kilde eller en kortpulset kilde, men langpulset

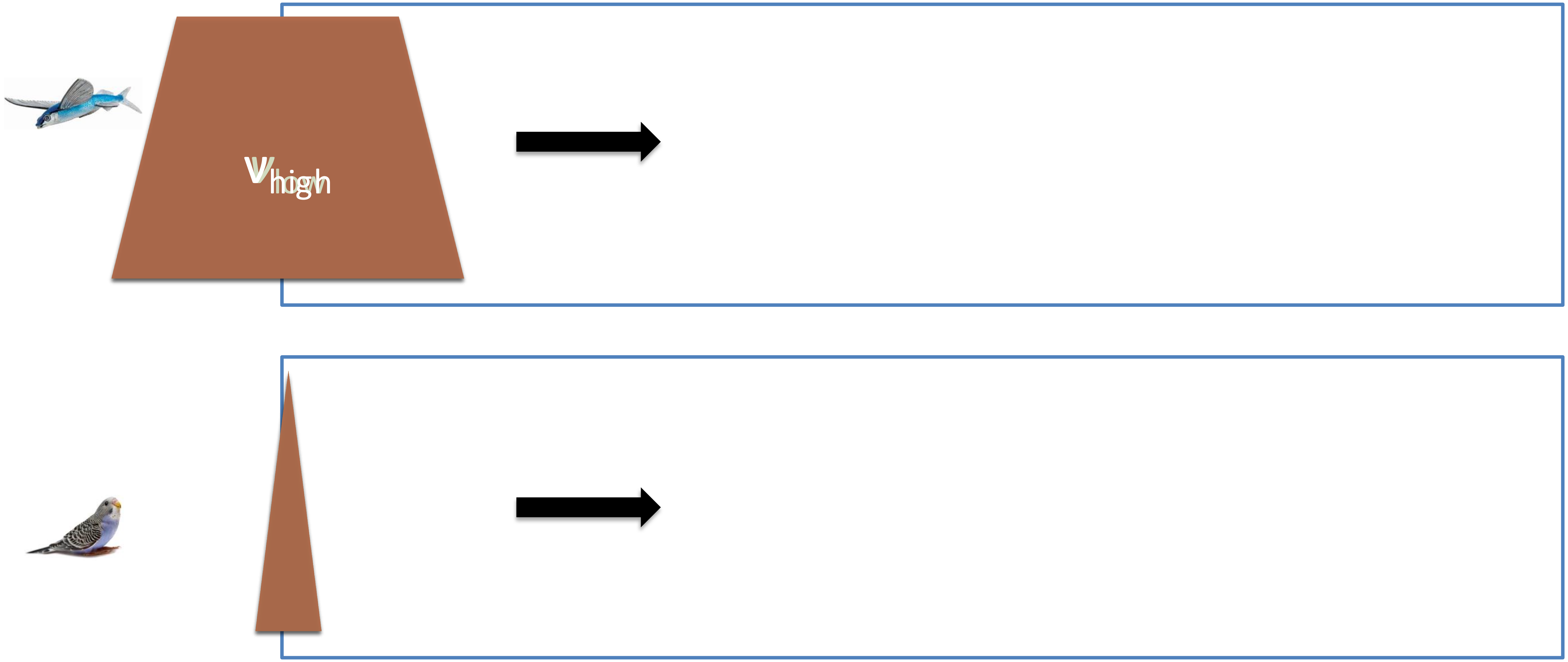


- Med *passende instrumentering* der tager højde for dette kan man opnå (mindst) 30 x ILL performance og 5-10 x kortpulset performance

Major neutron sources in the world



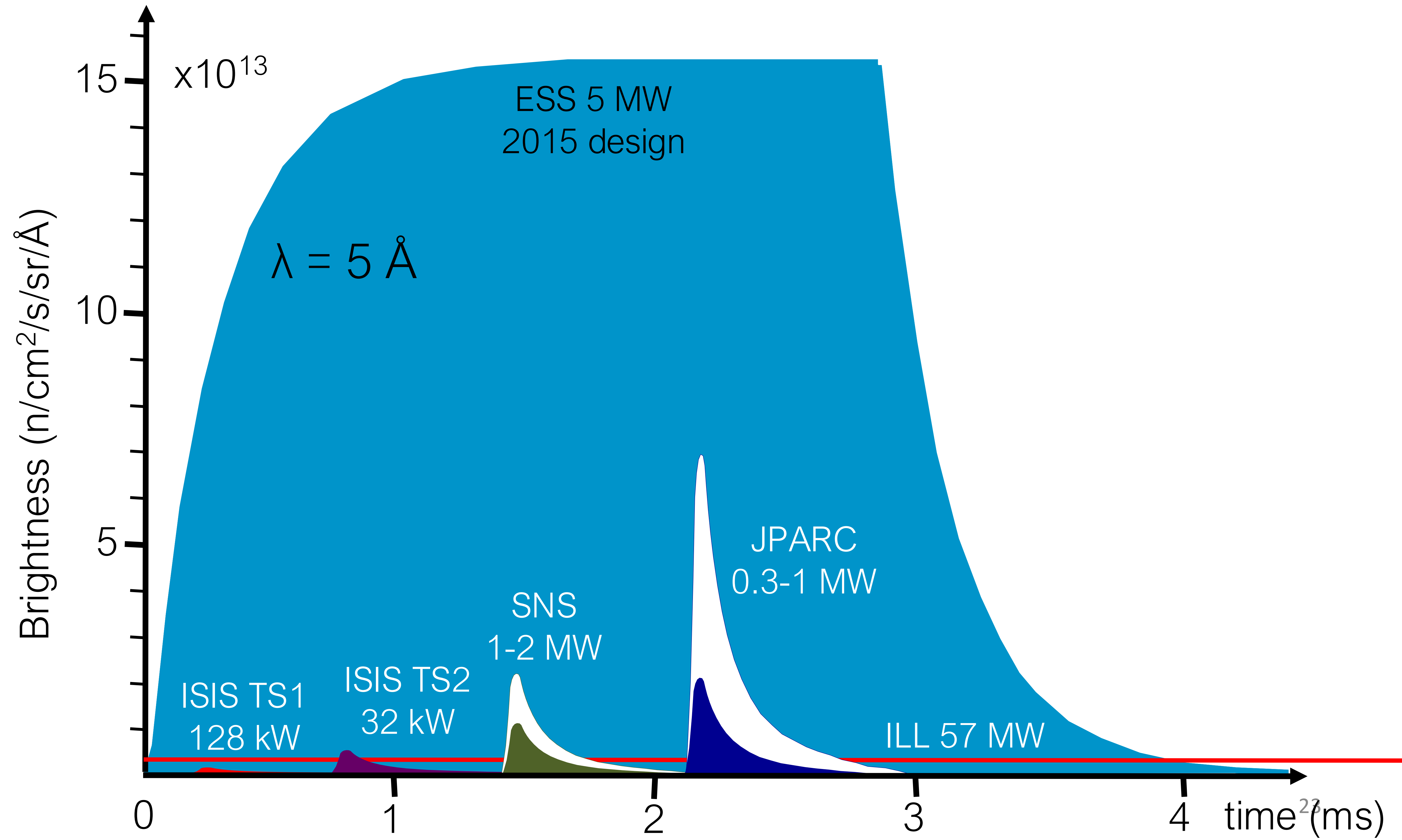
Lengths of beam line and pulse affect λ resolution



Neutron pulse

Beamline

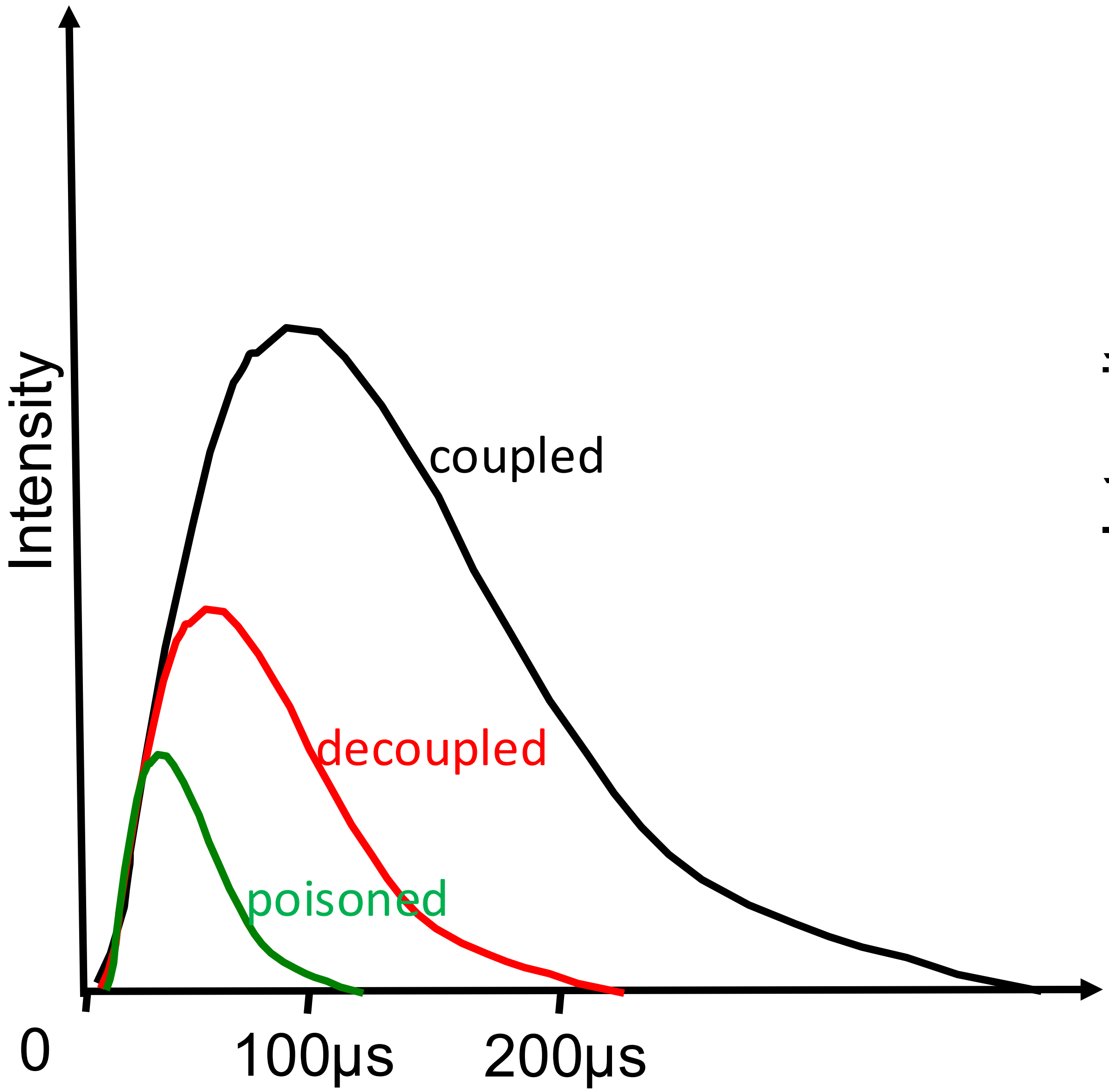
Long-pulse performance



Adapting the pulse width

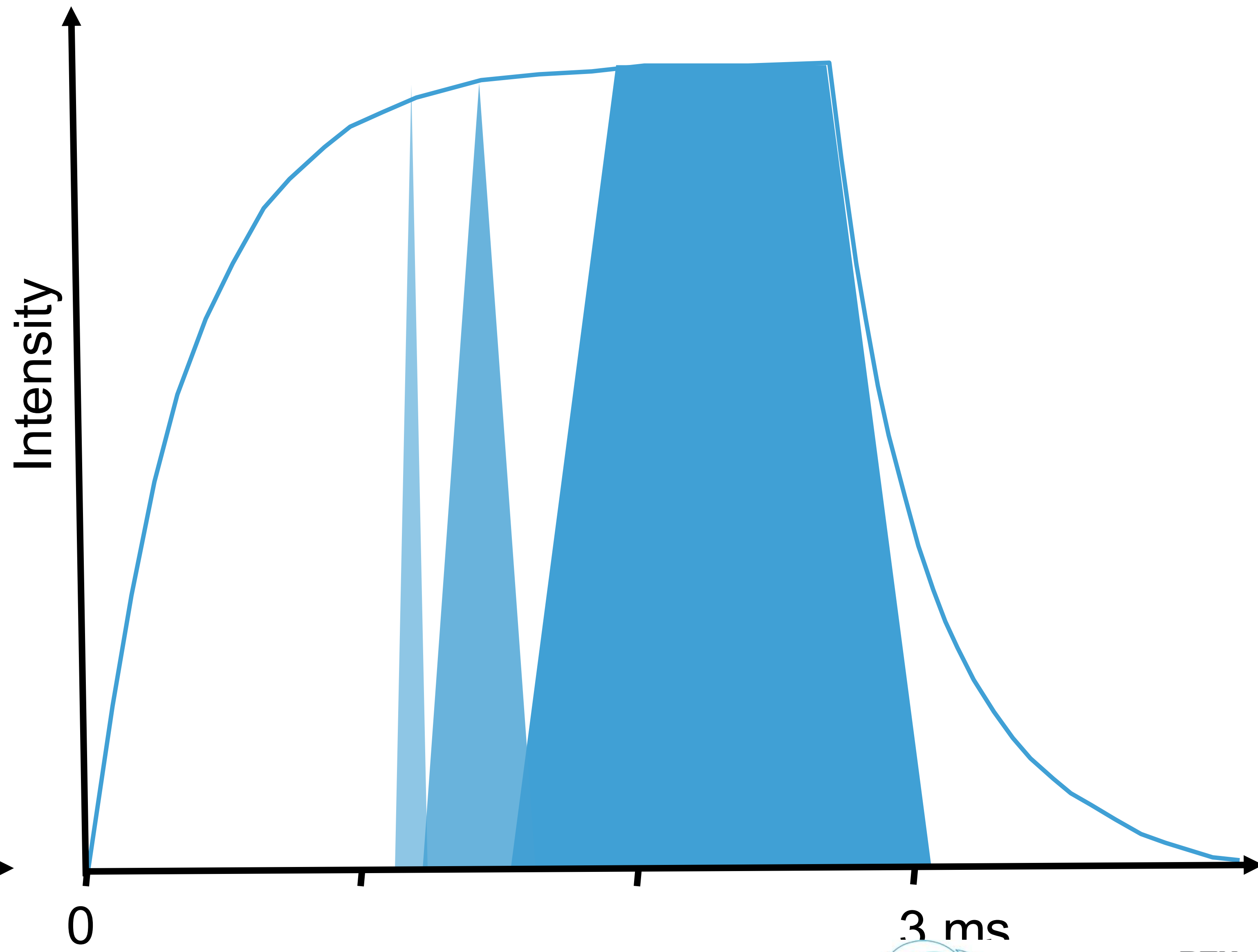
Short-Pulse Source

- set pulse width by choosing moderator

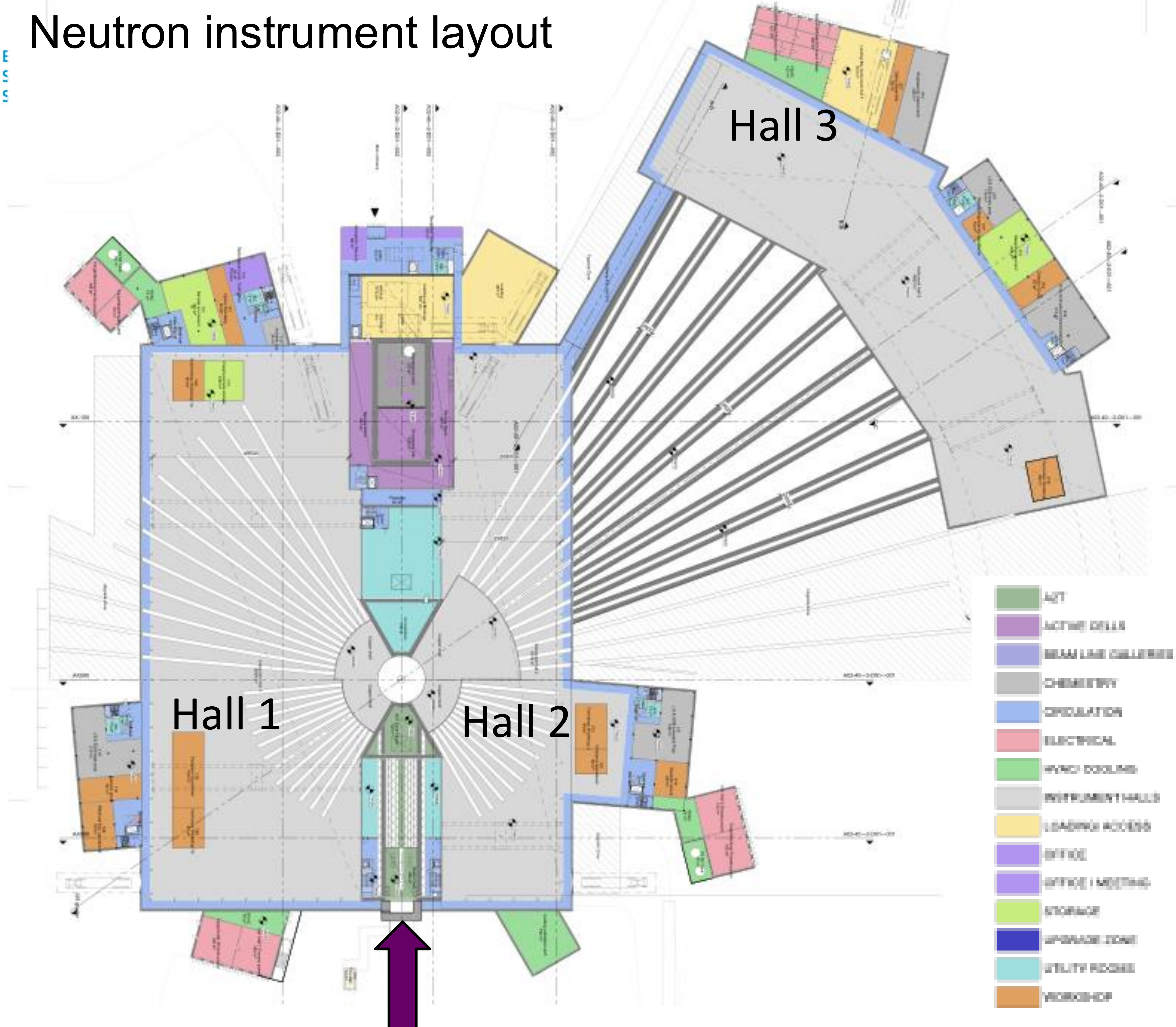


Long-Pulse Source (ESS)

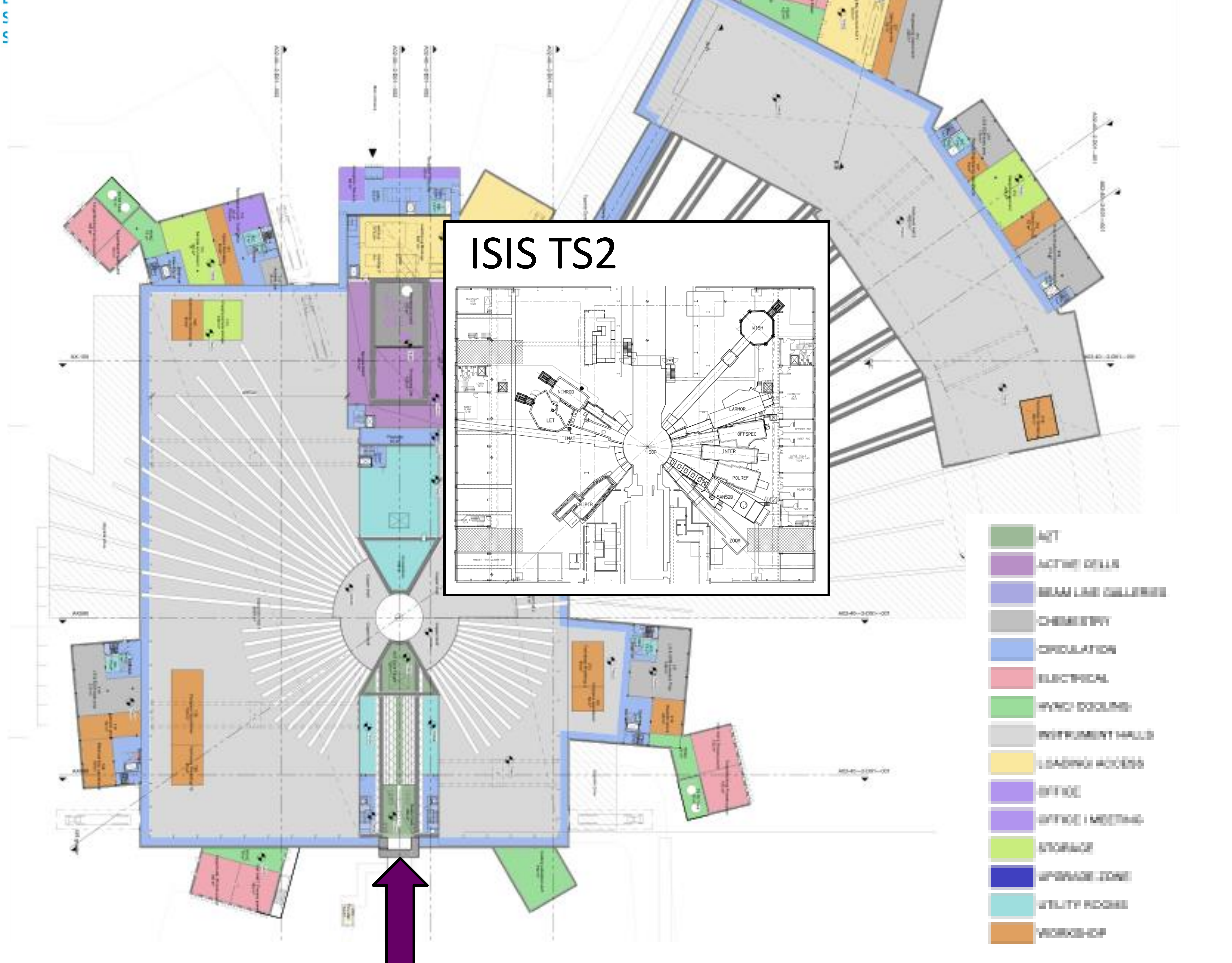
- set pulse width using pulse-shaping chopper



Neutron instrument layout



Neutron instrument layout



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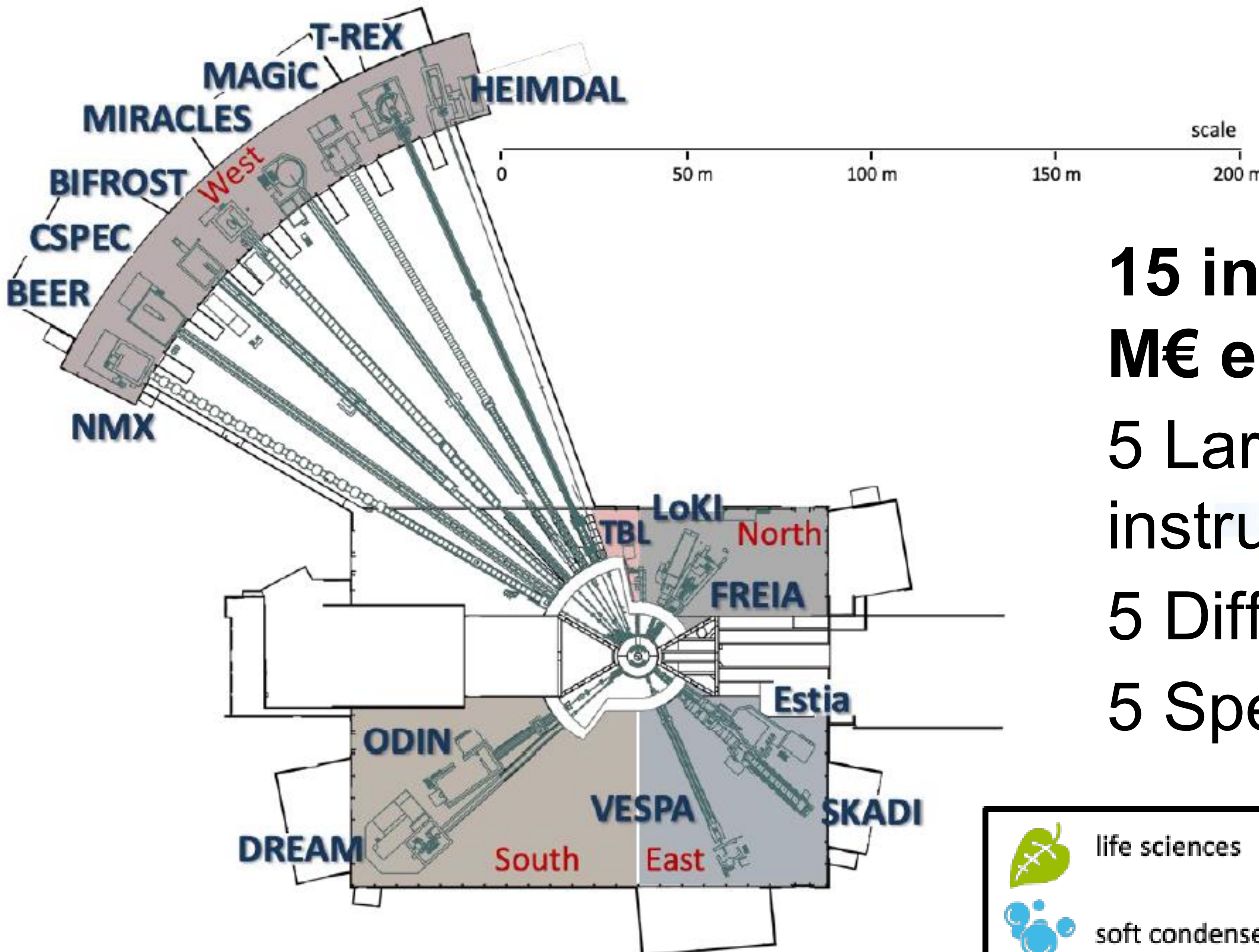
Instrument suite at ESS

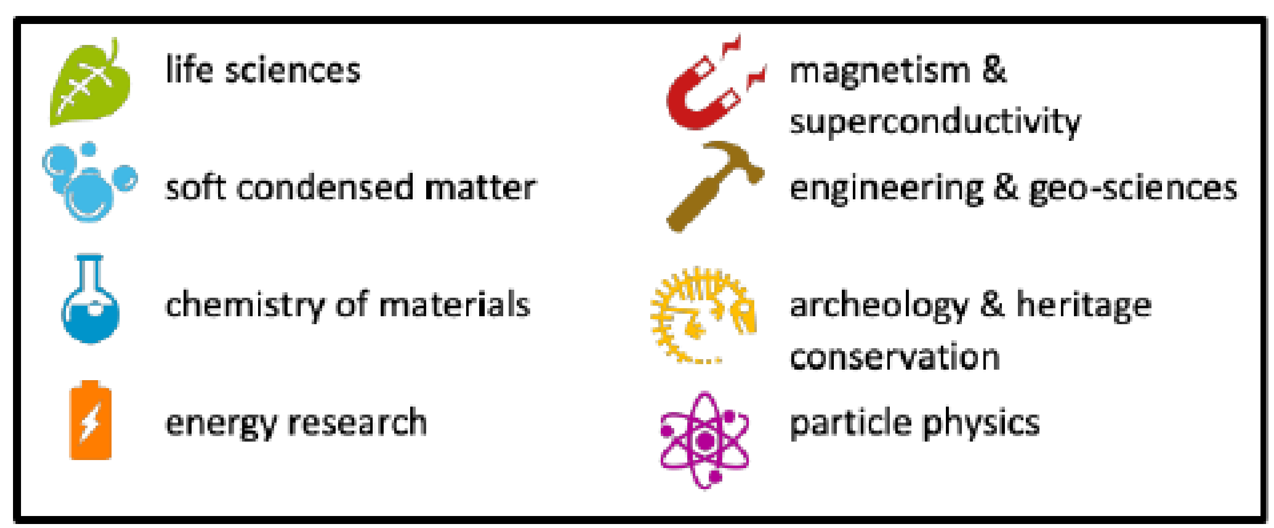


15 instruments (10-15 M€ each)

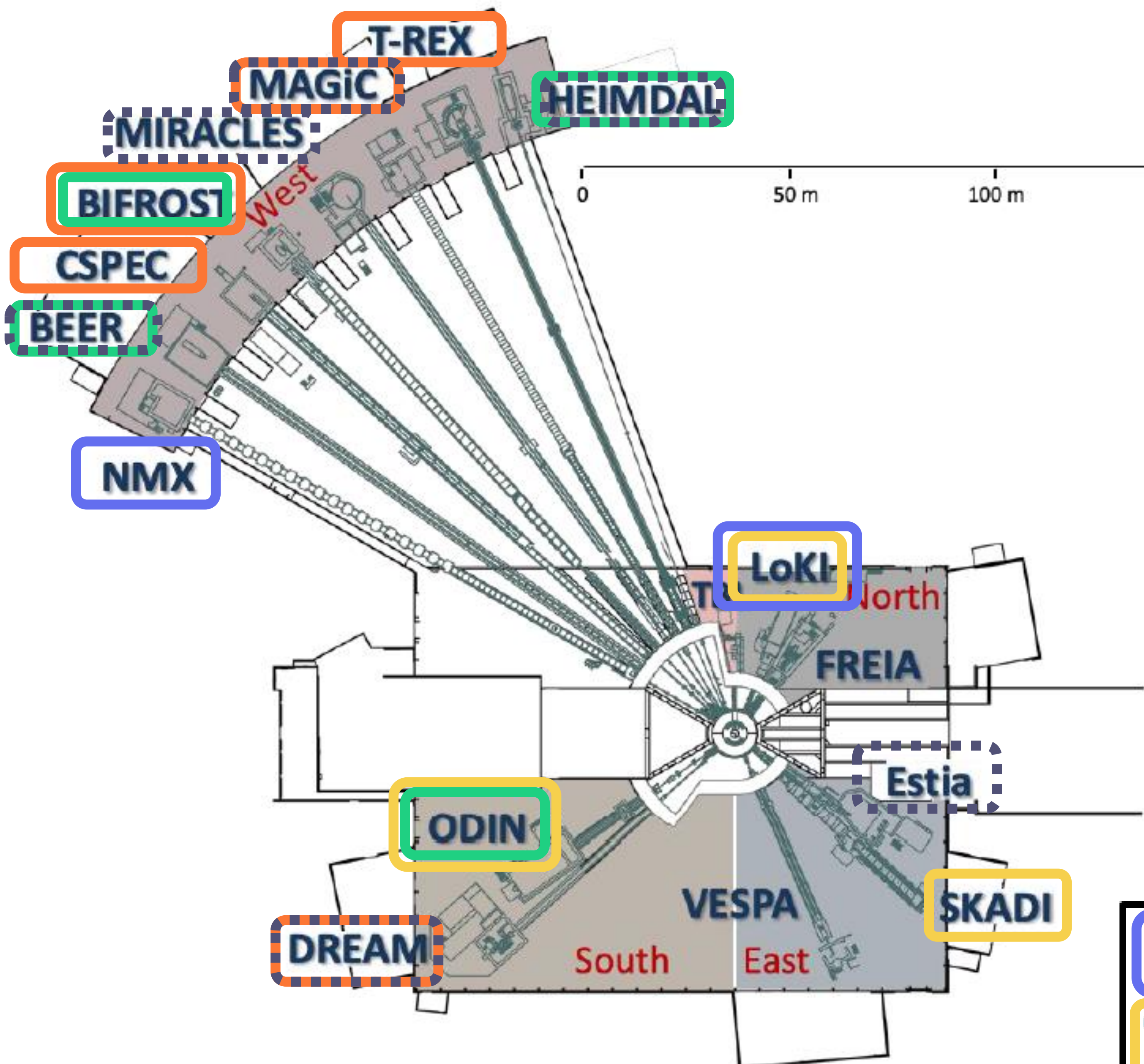
5 Large-scale structure instruments

5 Diffractometers

5 Spectrometer



Instrument suite at ESS



15 instruments (10-15 M€ each)

5 Large-scale structure instruments

5 Diffractometers

5 Spectrometer

*classification not official

- life sciences
- magnetism & superconductivity
- soft condensed matter
- engineering & geo-sciences
- chemistry of materials
- archeology & heritage conservation
- energy research
- particle physics

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Instrument suite at ESS

Large-Scale Structures

- ODIN Imaging Instrument
- SKADI General Purpose SANS
- LoKI Broadband SANS
- Surface Scattering
- FREIA Horizontal Reflectometer
- Estia Vertical Reflectometer

Diffraction

- HEIMDAL Powder Diffractometer
- DREAM Powder Diffractometer
- Monochromatic Powder Diffractometer
- BEER Engineering Diffractometer
- Extreme Conditions Diffractometer
- MAGiC Magnetism Diffractometer
- NMX Macromolecular Diffractometer

Spectroscopy

- CSPEC Cold Chopper Spectrometer
- Broadband Spectrometer
- T-REX Thermal Chopper Spectrometer
- BIFROST Crystal Analyser Spectrometer
- VESPA Vibrational Spectroscopy
- MIRACLES Backscattering Spectrometer
- High-Resolution Spin-Echo
- Wide-Angle Spin-Echo
- Particle Physics Beamline

life sciences

soft condensed matter

chemistry of materials

energy research

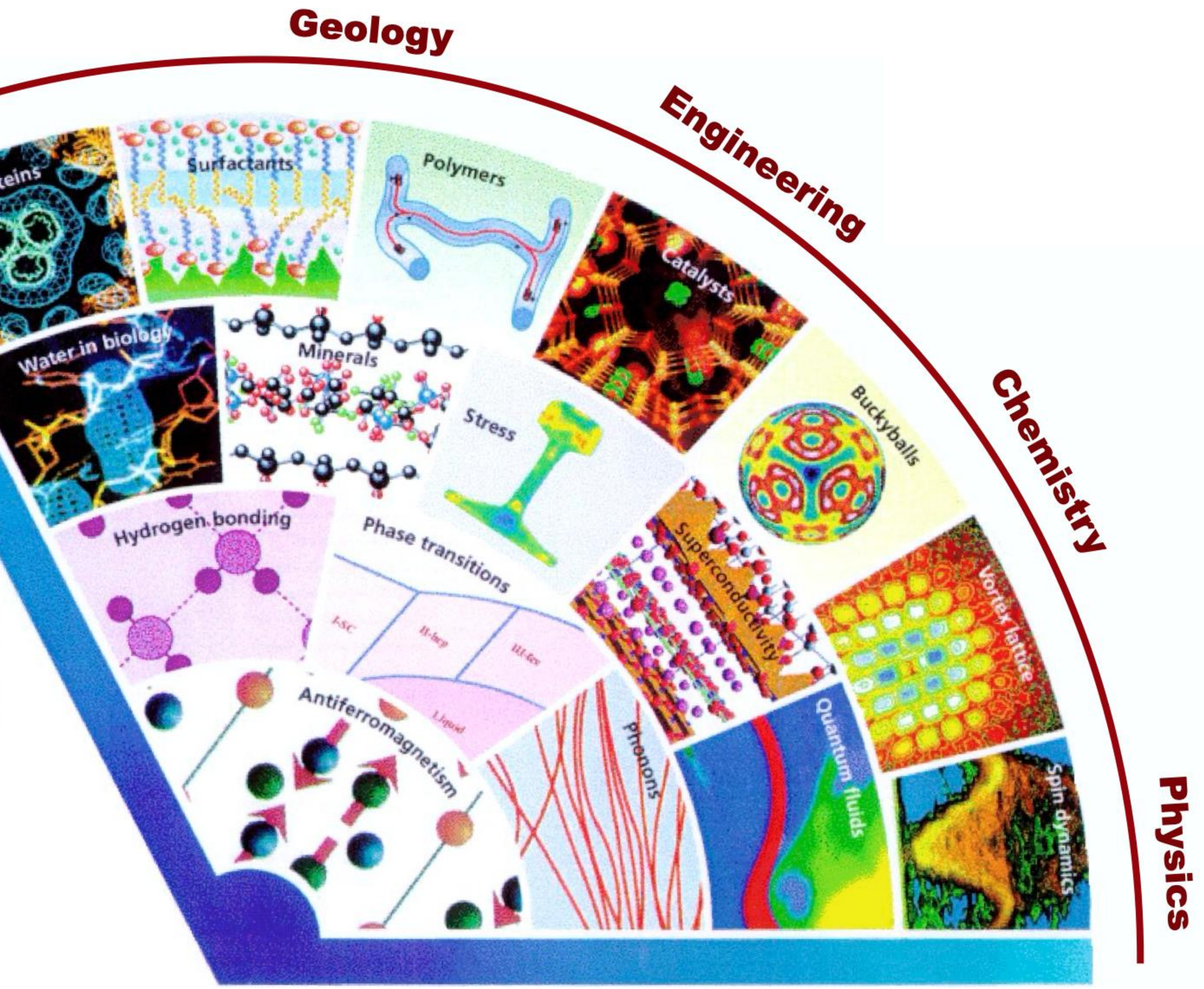
magnetism & superconductivity

engineering & geo-sciences

archeology & heritage conservation

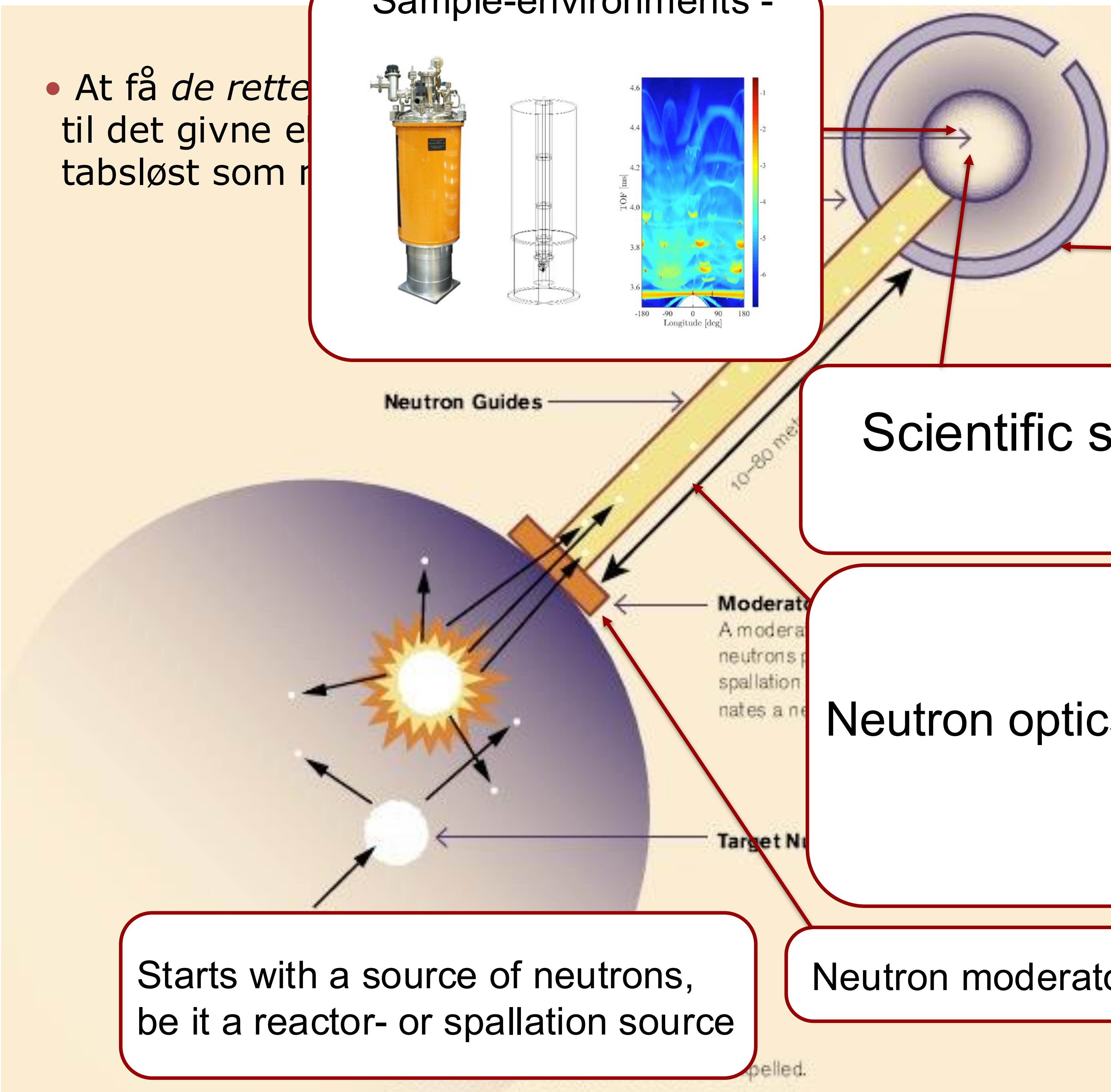
particle physics

Broad length and time scales



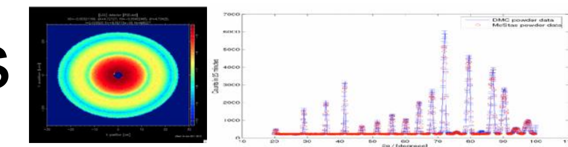
Components of neutron instruments

- At få *de rette*
til det givne e
tabsløst som m

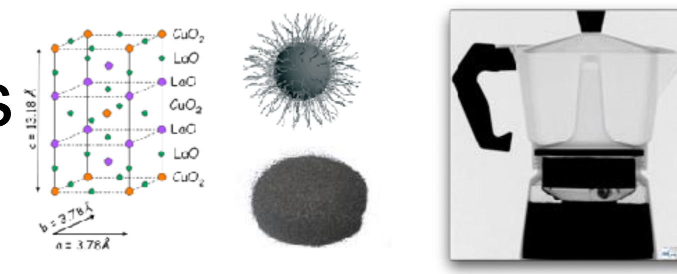


Sample-environments -

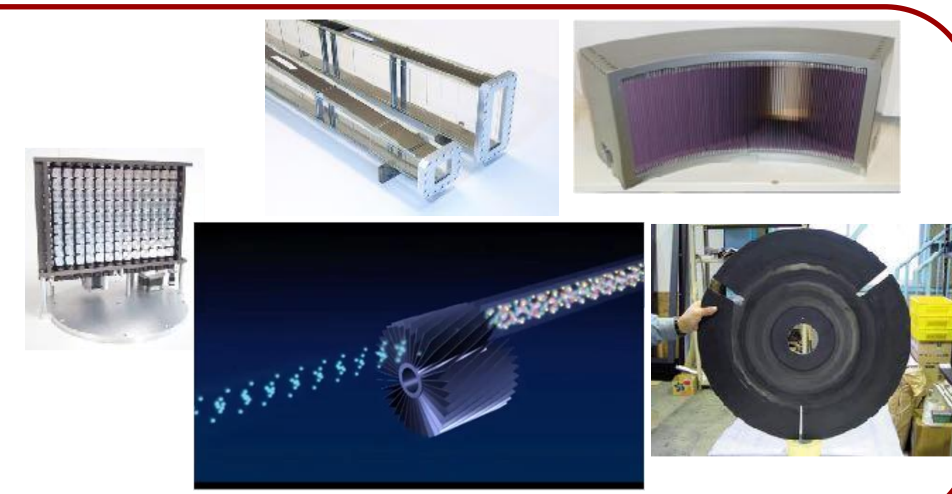
Detectors
s



Scientific samples



Neutron optics



Starts with a source of neutrons, be it a reactor- or spallation source

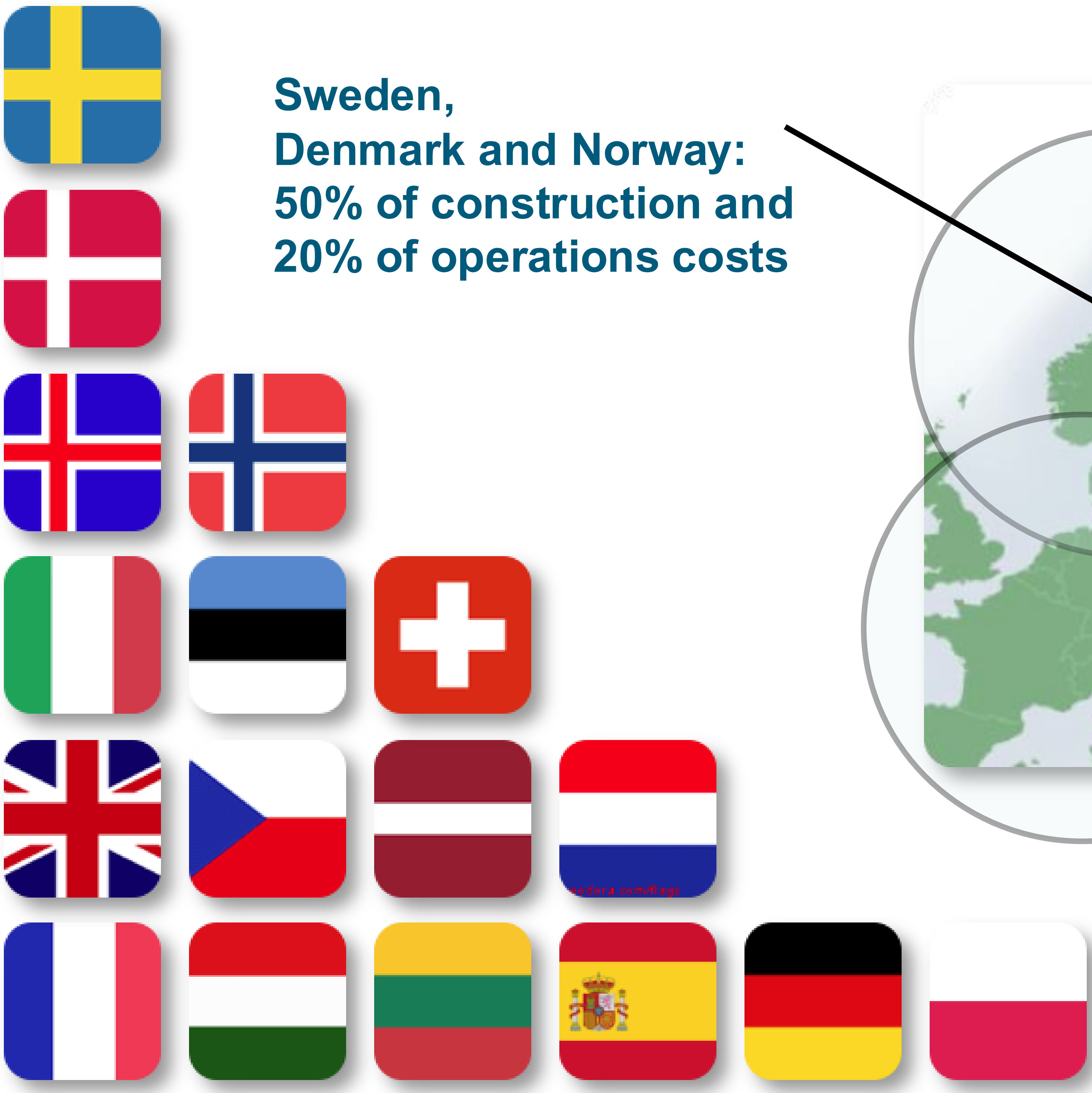
Neutron moderator

The European Spallation Source

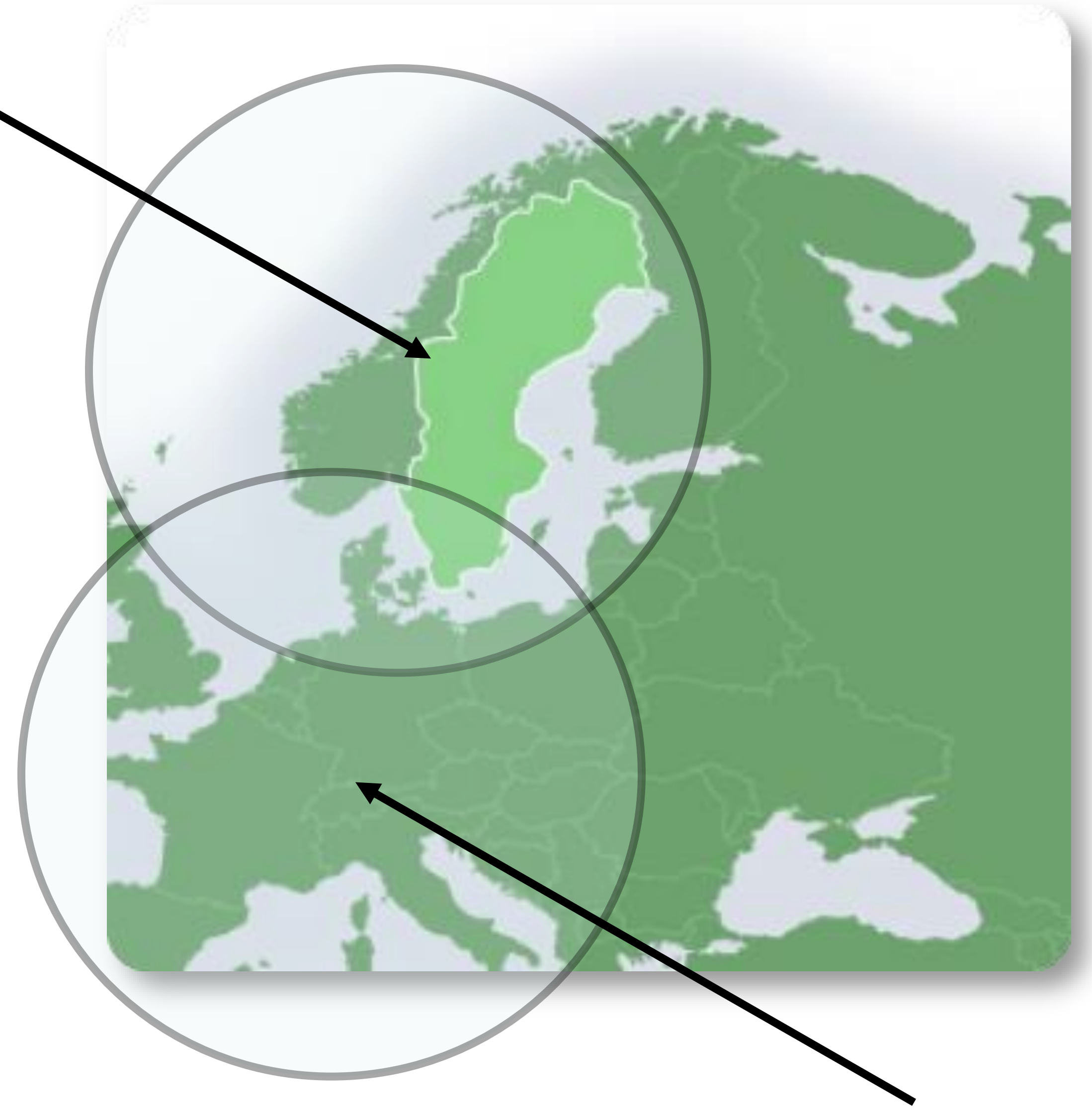
Host countries: Sweden, Denmark

Partner countries: Czech Republic, Estonia, France, Germany, Hungary, Italy, Norway, Poland, Spain, Switzerland and the United Kingdom

An International Collaboration



Sweden,
Denmark and Norway:
50% of construction and
20% of operations costs



European partners
pays the rest

The ESS Instrument Suite 15/22

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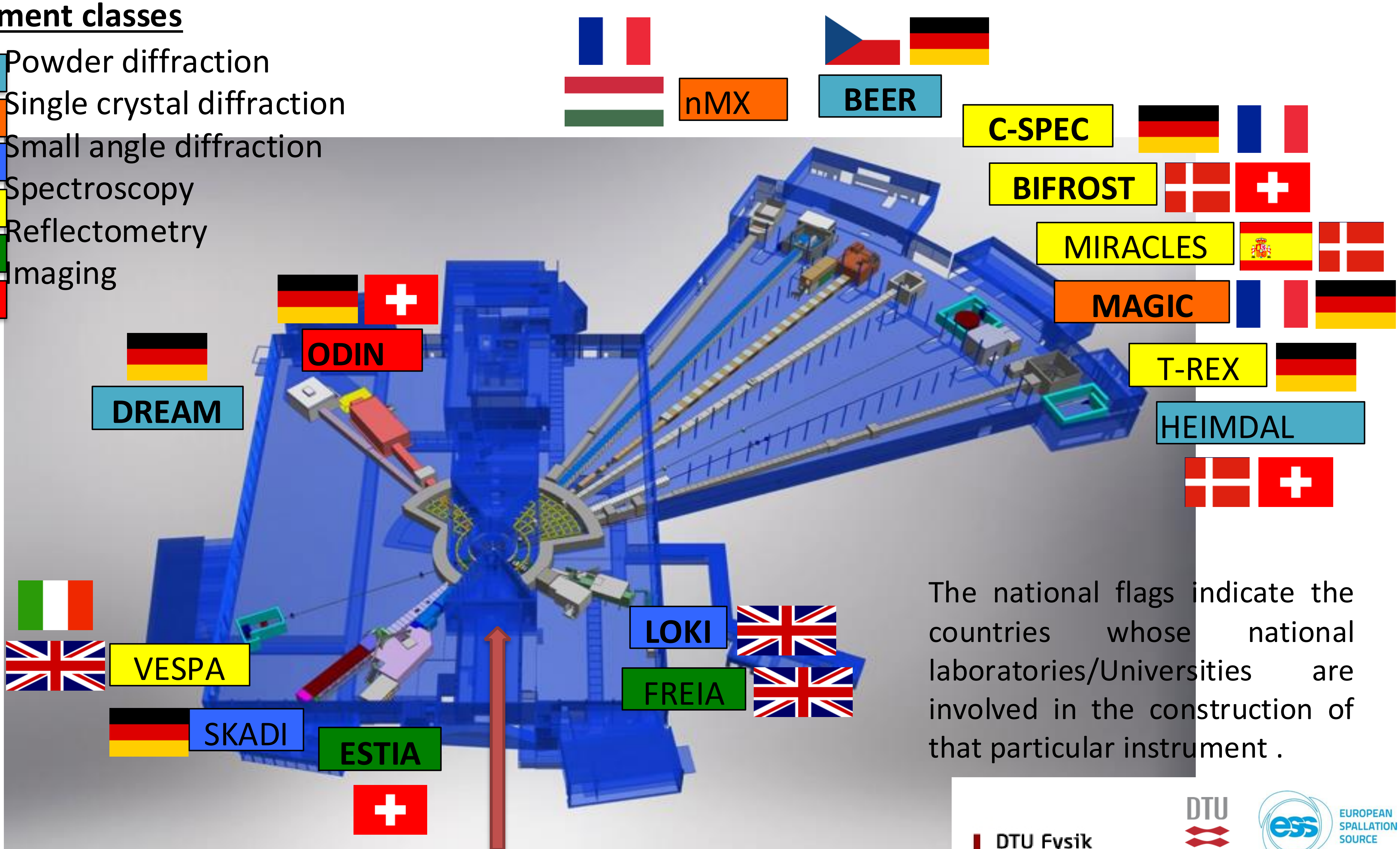
Instrument classes

- Powder diffraction
- Single crystal diffraction
- Small angle diffraction
- Spectroscopy
- Reflectometry
- Imaging



The national flags indicate the countries whose national laboratories/Universities are involved in the construction of that particular instrument .

DTU Fysik
Institut for Fysik

DTU

EUROPEAN SPALLATION SOURCE

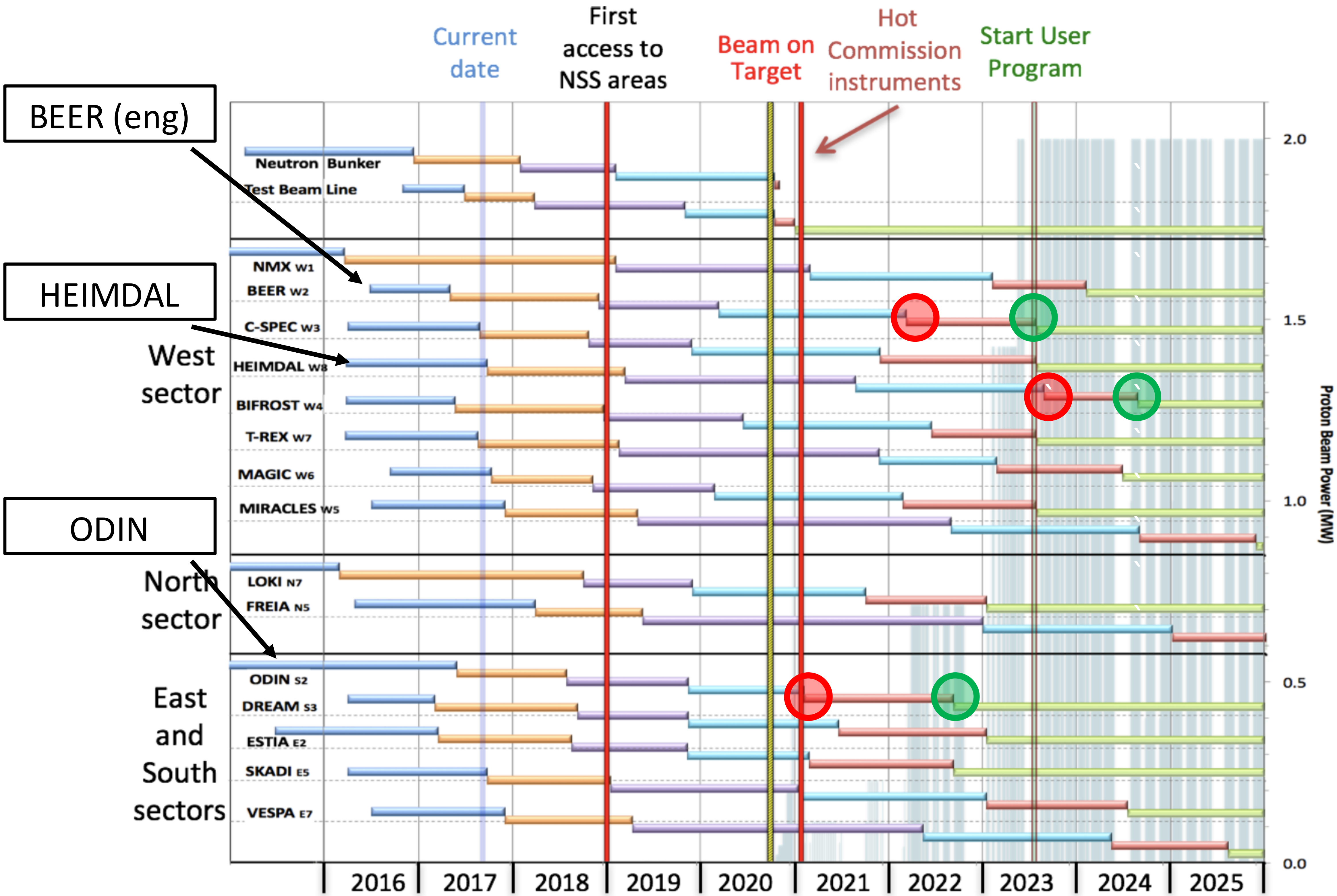
The Data Management and Software Centre

Topic of later, dedicated talk…

- Data Management
- Instrument Control
- Data Reduction & Analysis
- Instrument simulations
- (Theory and simulations)

High-level instrument construction schedule

(ældre version – tiden er skredet lidt, men der er *virkelig* stadig gang i den…)



Questions