Hungary for ess
EUROPEAN SPALLATION SOURCE PROJECT

New challenge: the ESS

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Summary

- **ESS: why?**
- **How?**
- **(Why in Debrecen?)**

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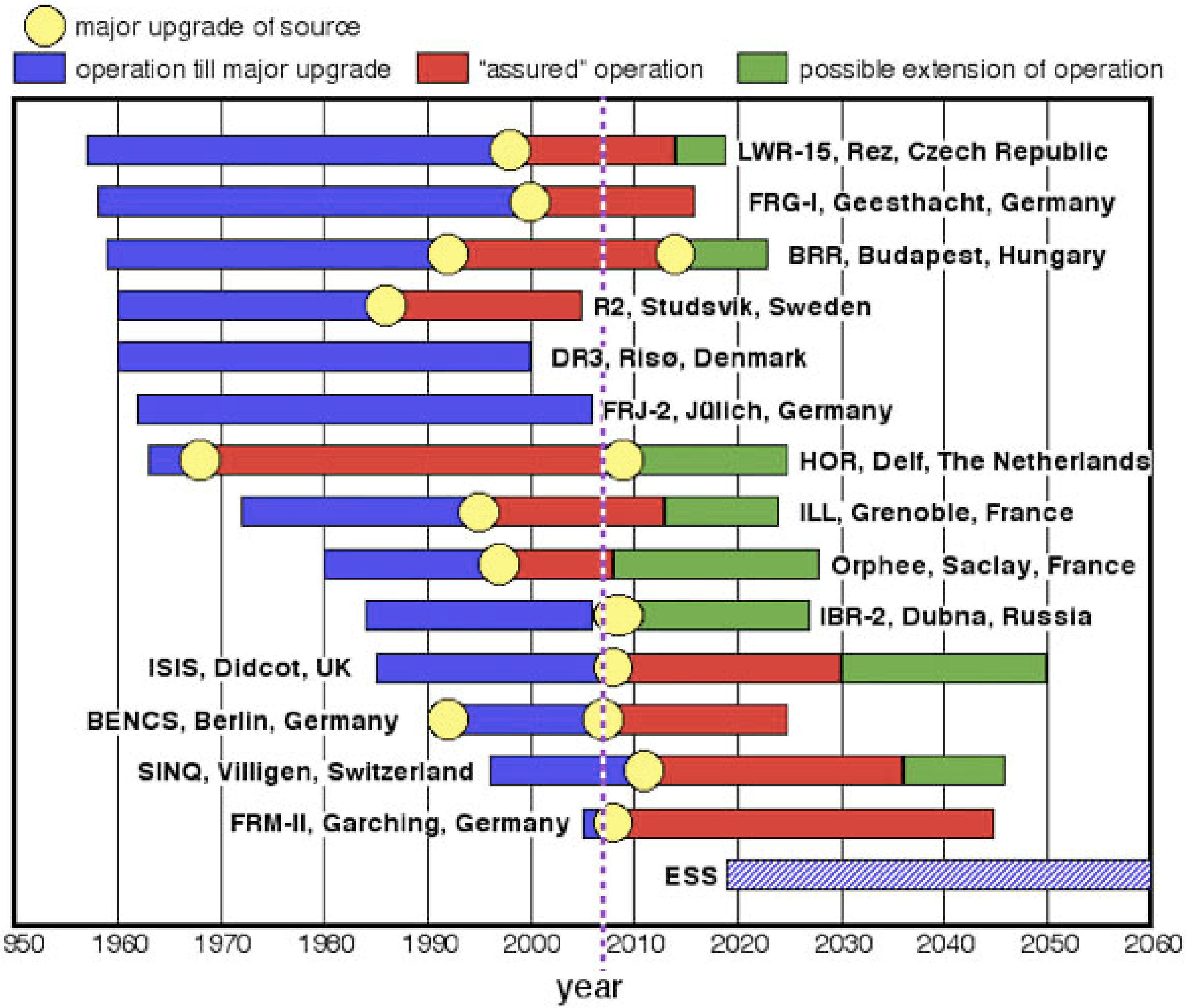
Neutron research in Europe:

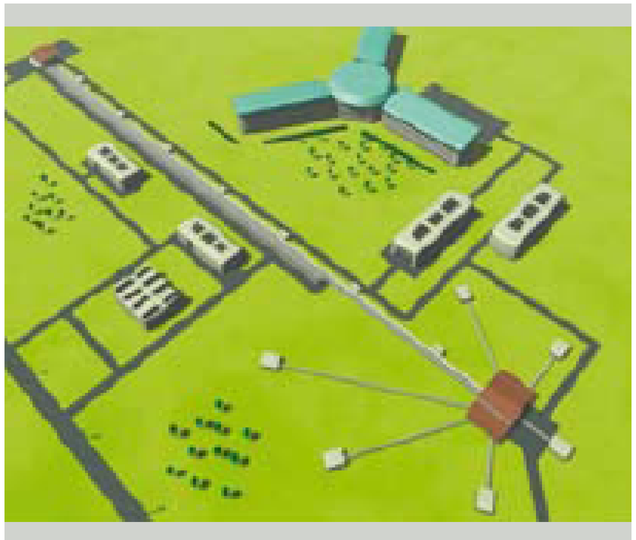
~4000 scientists, 11 facilities (and decreasing): ~ 330 M€/a



- ESFRI 2006 road map:

need for “top tier” neutron source for Europe

ESS will be the world's most powerful source of neutrons. Its built-in upgradeability (more than the initial 20 instruments, more power, more target stations) makes it the most cost-effective top tier source for 40 years or more. A genuine pan-European facility, it will serve 4,000 users annually across many areas of science and technology.



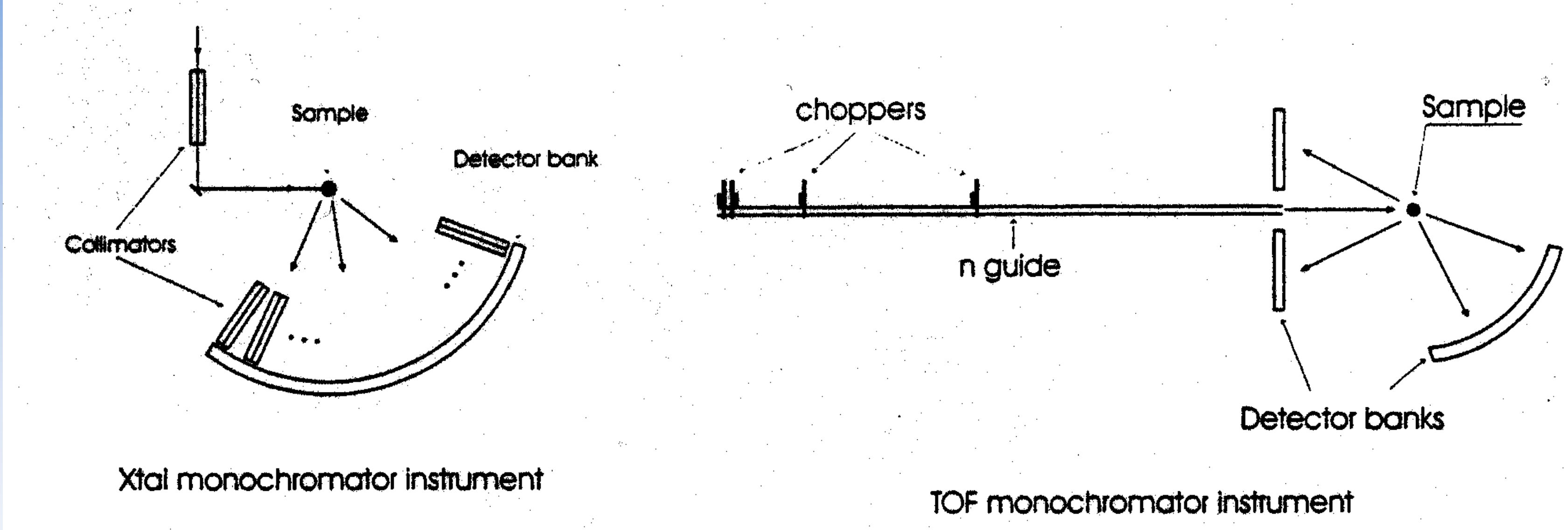
Energy efficiency is key for high intensity neutron beam production: fast neutrons produced / joule energy or heat

Fission reactors:	~ 10^9	(in ~ 50 liter volume)
Spallation:	~ 10^{10}	(in ~ 2 liter volume)
Fusion:	~1.5×10^{10}	(in ~ 2 liter volume)
	(but neutron slowing down efficiency reduced by ~20 times)	
Photo neutrons:	~ 10^9	(in ~ 0.01 liter volume)
Nuclear reaction (p, Be):	~ 10^8	(in ~ 0.001 liter volume)
Laser induced fusion:	~ 10^4	(in ~ 10^{-9} liter volume)

Spallation: most favourable for the foreseeable future

Pulsed source provides for more efficient use of the neutrons produced:

by the use of time-of-flight (TOF) methods:



E.g. powder diffraction (idea by Buras, ~1960)

Potential efficiency gain: switch off source between chopper pulses

Pulsed source provides for more efficient use of the neutrons produced:

by the use of time-of-flight (TOF) methods

Total gain potential in efficiency:

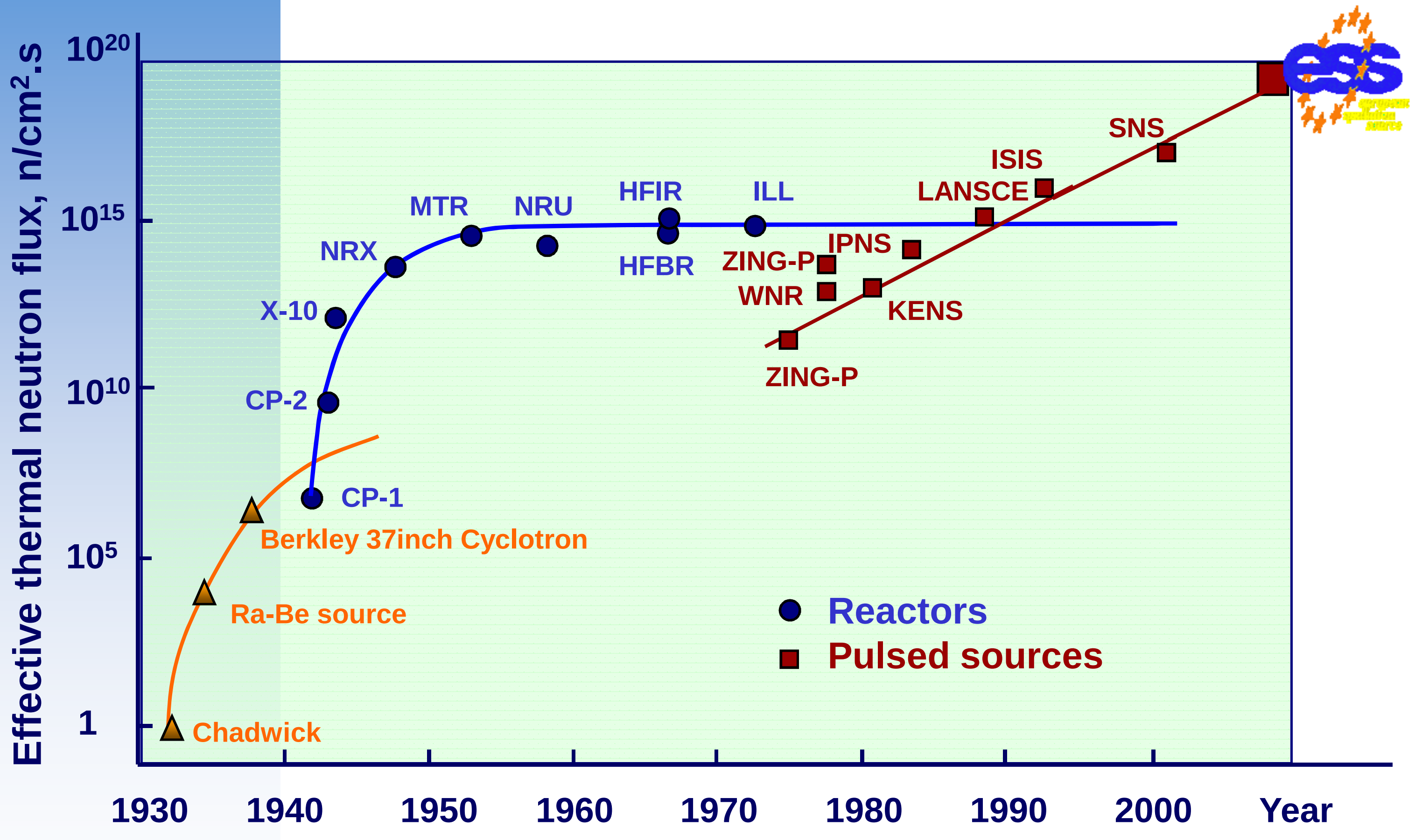
x 6 energy of neutron production

x 10 – 100 by TOF on pulsed sources

⇨ Quantum leap in performance:

5 MW ESS: start with as many neutrons as e.g. ILL: the FIRST CHALLENGE of the NEXT GENERATION

Progress in neutron sources



Summary

- ESS: why?
- How?
- (Why in Debrecen?)

Development of neutron sources

- Parasitic use of energy research reactors (1949…)
- Dedicated neutron beam reactors (1958,….)
- ILL (1972): limit of power at reasonable costs
- Pulsed sources (1960's, Dubna):
  more efficient use of fewer neutrons produced
- Spallation sources (1970's,…)
  less heat / energy per neutron produced
- MW class pulsed spallation sources (SNS, J-PARC)
  Leap in source performance to surpass ILL:
  fewer neutrons more efficiently produced and used
- SNS & J-PARC: reach limits of traditional pulsed spallation source technology:
  shock waves in target,
  space charge in accelerator ring,….

"Short" proton pulses using accelerating (or storage) rings:

- ~ 1 μs pulse length, huge instantaneous heat deposition (~ 15 GW for 23 kj/pulse of SNS)

~ 15 x

- Proton pulse length poorly matches the 10 – 300 μs neutron moderator response time
- Pulse lengths < 4 ms meets resolution requirements in some key applications (e.g. SANS, NSE)

SNS (Oak Ridge, USA):
successfully achieved 0.5 MW power !! (goal 1.4 MW)

“Long” proton pulses using linear accelerators:

- **Linear accelerators can produce the same beam energy per pulse in ~ 100 μs pulses at much reduced costs**

~ 60 % of accelerator parts and complexity removed

"Long" proton pulses using linear accelerators:

• Longer - hence more intense - pulses (ms) are advantageous for cold and thermal neutron applications: > 10^{14} n/cm²/pulse (compared to < 10^{13} for SNS) at instantaneous power of ~ 90 MW

1.5 x

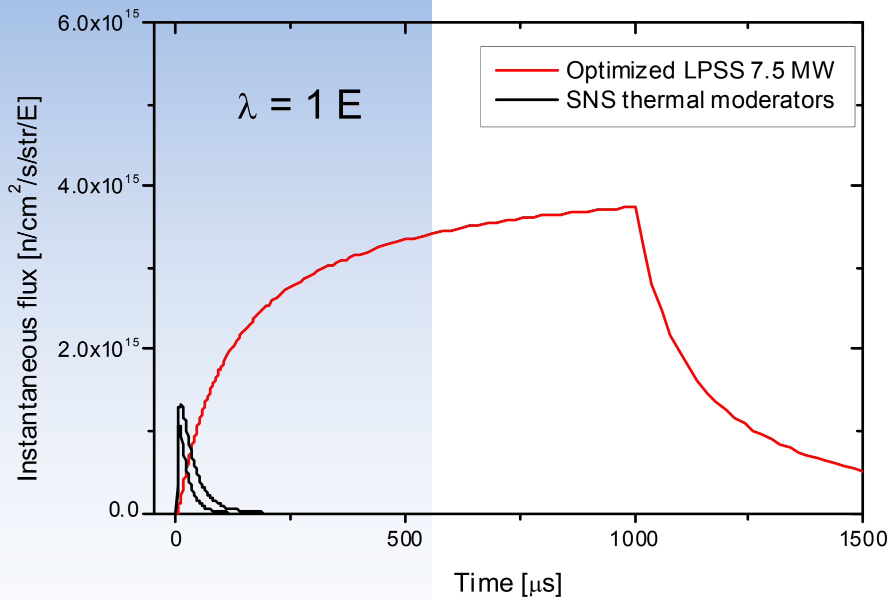
• Total energy per pulse of a few hundred kJ is household experience (ESS: 300 kJ/pulse)

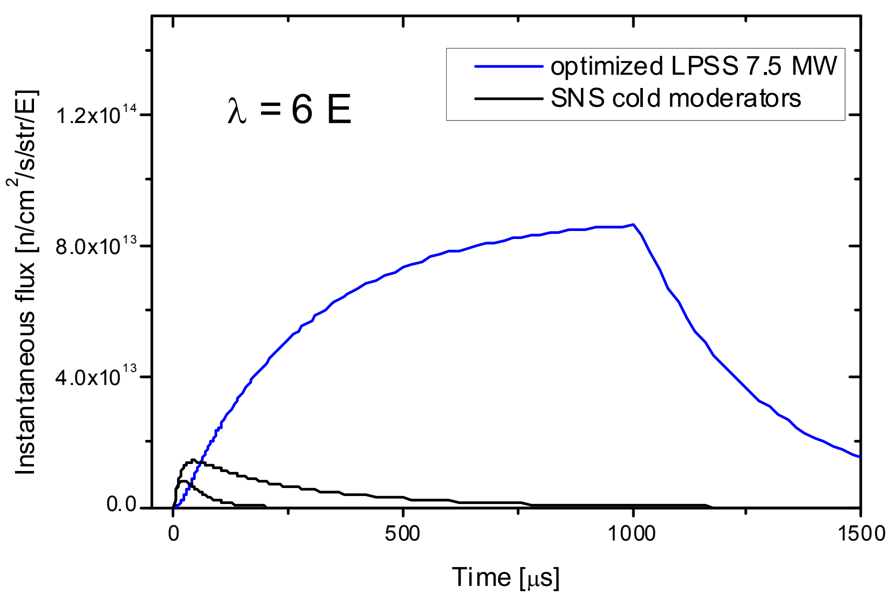
LP target operation:
to 98 % in thermohydraulic equilibrium
(vs. 100 % non-equilibrium for short pulses)

"Long" proton pulses using linear accelerators:

- **Longer - hence more intense - pulses (ms) also provide higher peak flux at comparable costs and technical complexity**

Example (> ESS reference power):
450 kj/pulse long pulses **(350 MW inst.)** vs 23 kj/pulse short pulse **(15 GW inst.**: SNS)



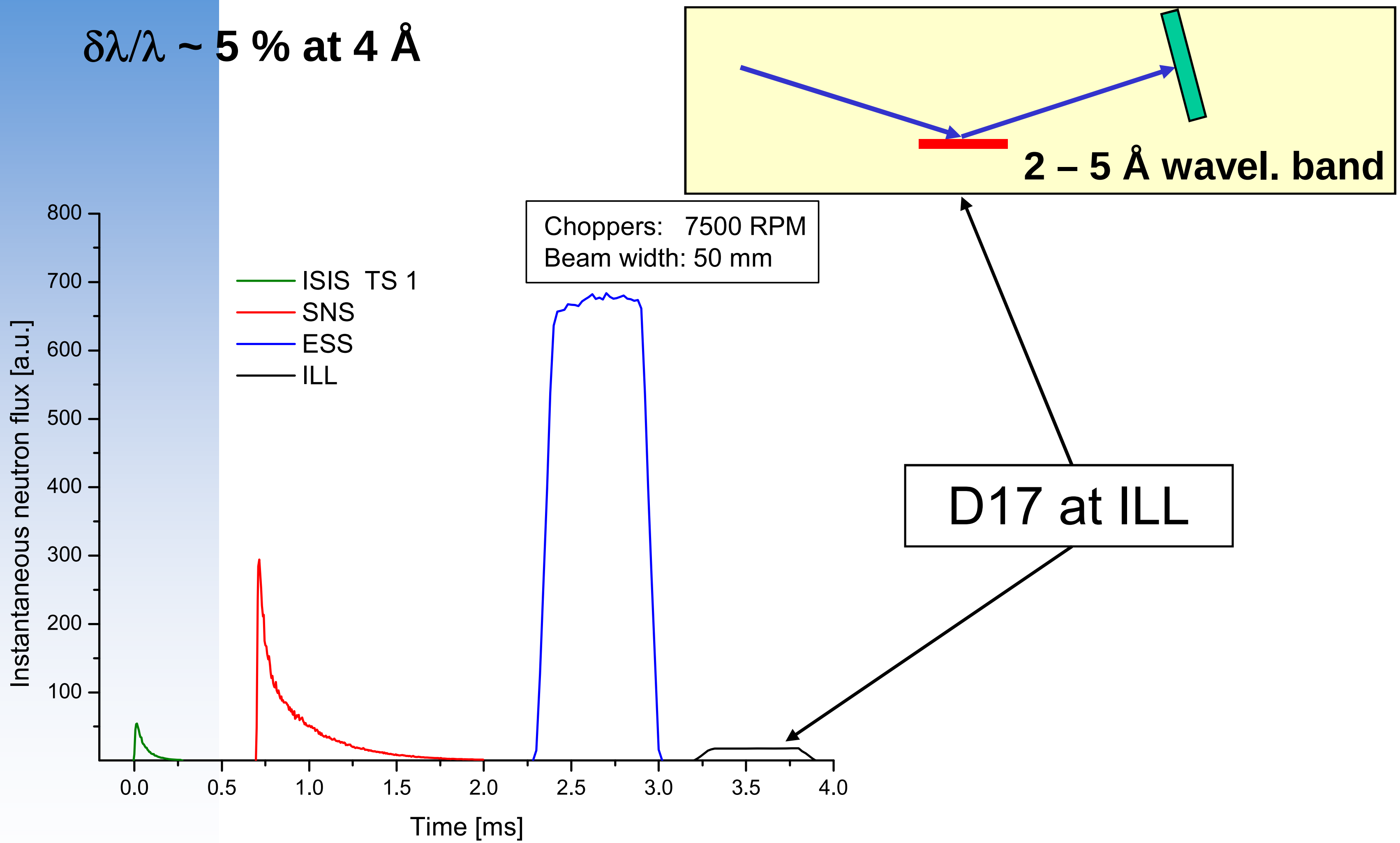


Fully new perspectives!

Huge gain in useful neutron intensity

Example: reflectometer (~15 m)

δλ/λ ~ 5 % at 4 Å



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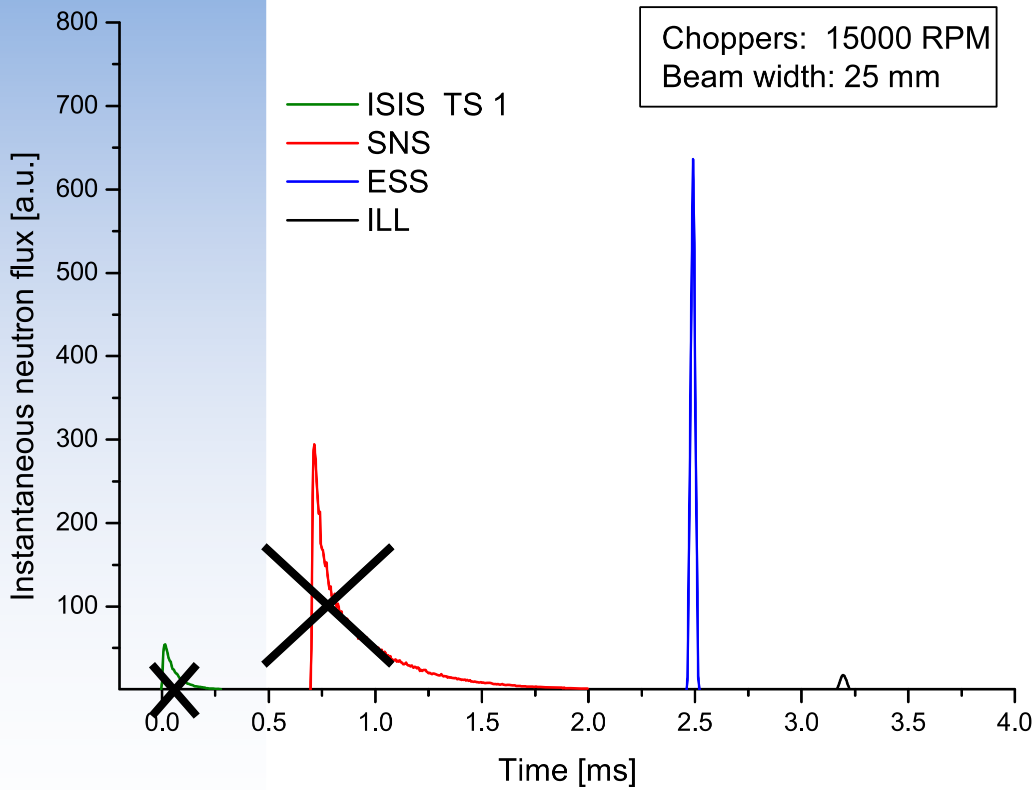


New capability: very high resolution

More efficient option with identical result:

-extend pulse length

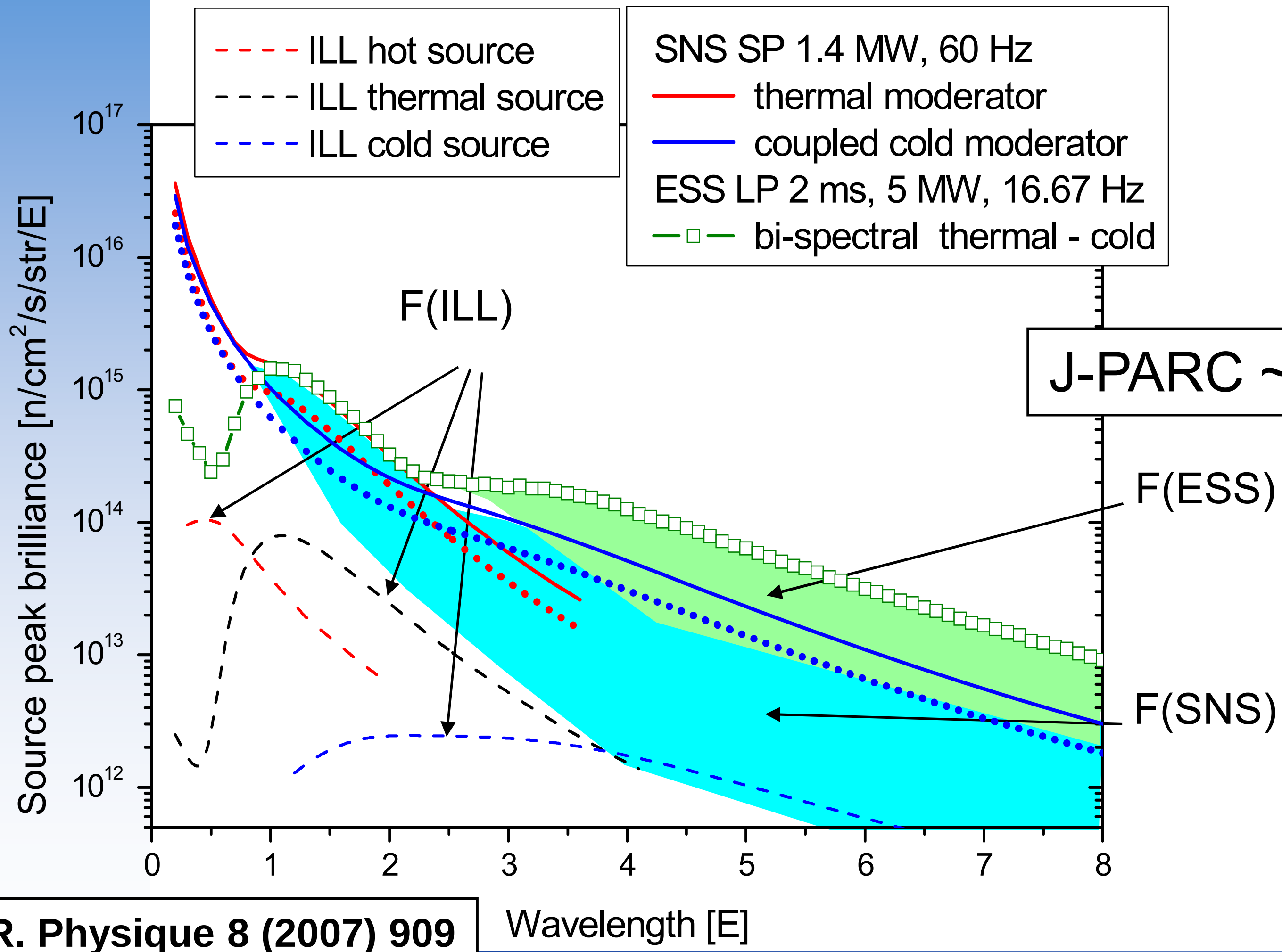
-extend instr. Length

-reduce pulse rate

→ **ESS: 16.67 Hz**

Source figure-of-merit (F):

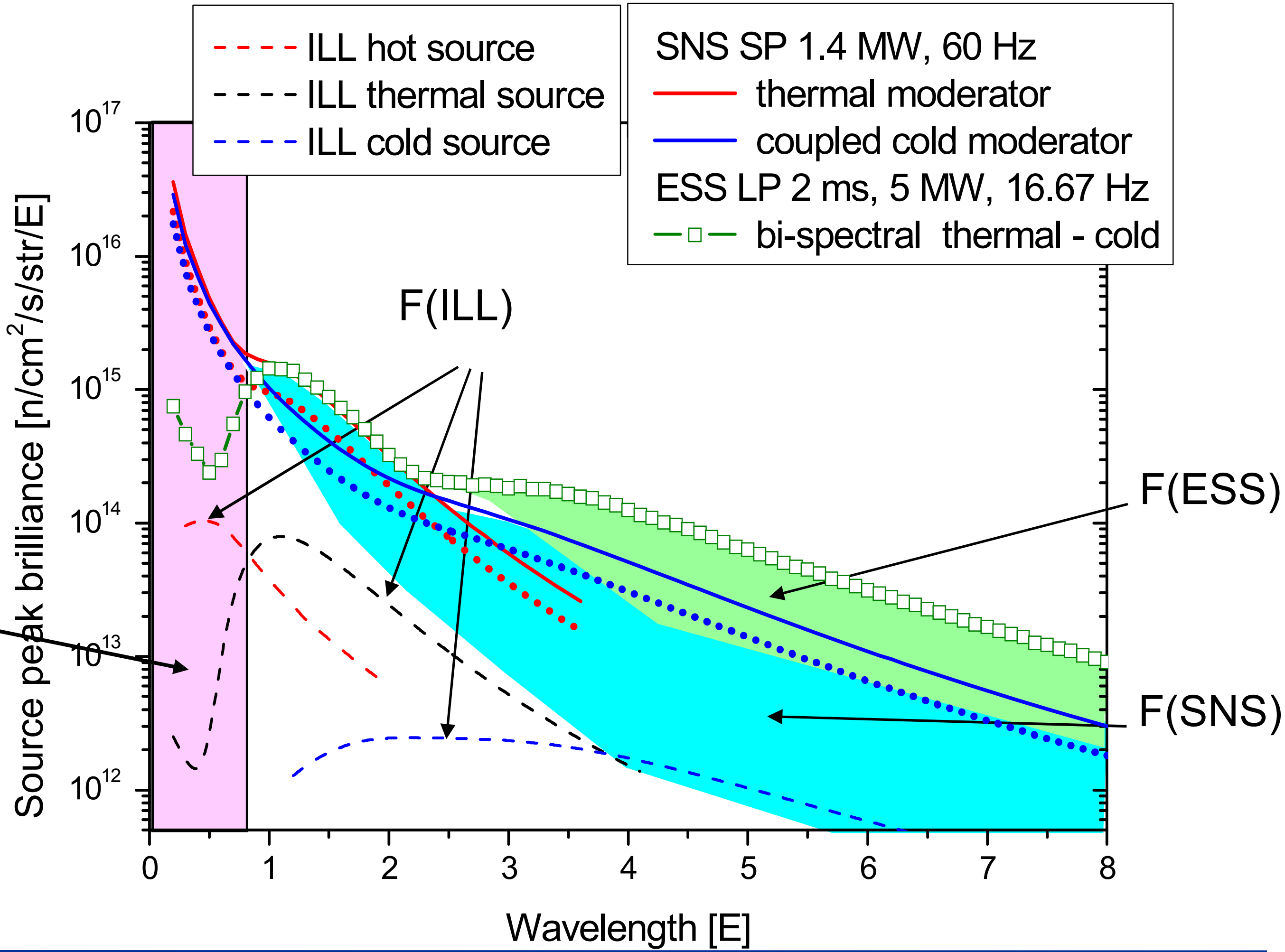
peak brilliance, if the well shaped pulses are long enough to avoid excessive resolution



F. Mezei, C.R. Physique 8 (2007) 909
www.sciencedirect.com

Source figure-of-merit (F): time average flux, if only one point in (Q, ω) space is of interest (e.g. polarization analysis in single crystals, CRYOPAD,…)

Hot neutrons (λ < 0.7 Å): relatively small chapter of neutron research, well served by existing reactors with hot source and SP sources



Short pulse source: optimized for hot neutrons

Long pulse source: optimized for cold neutrons

Conservative, well established technologies,

Innovative use,

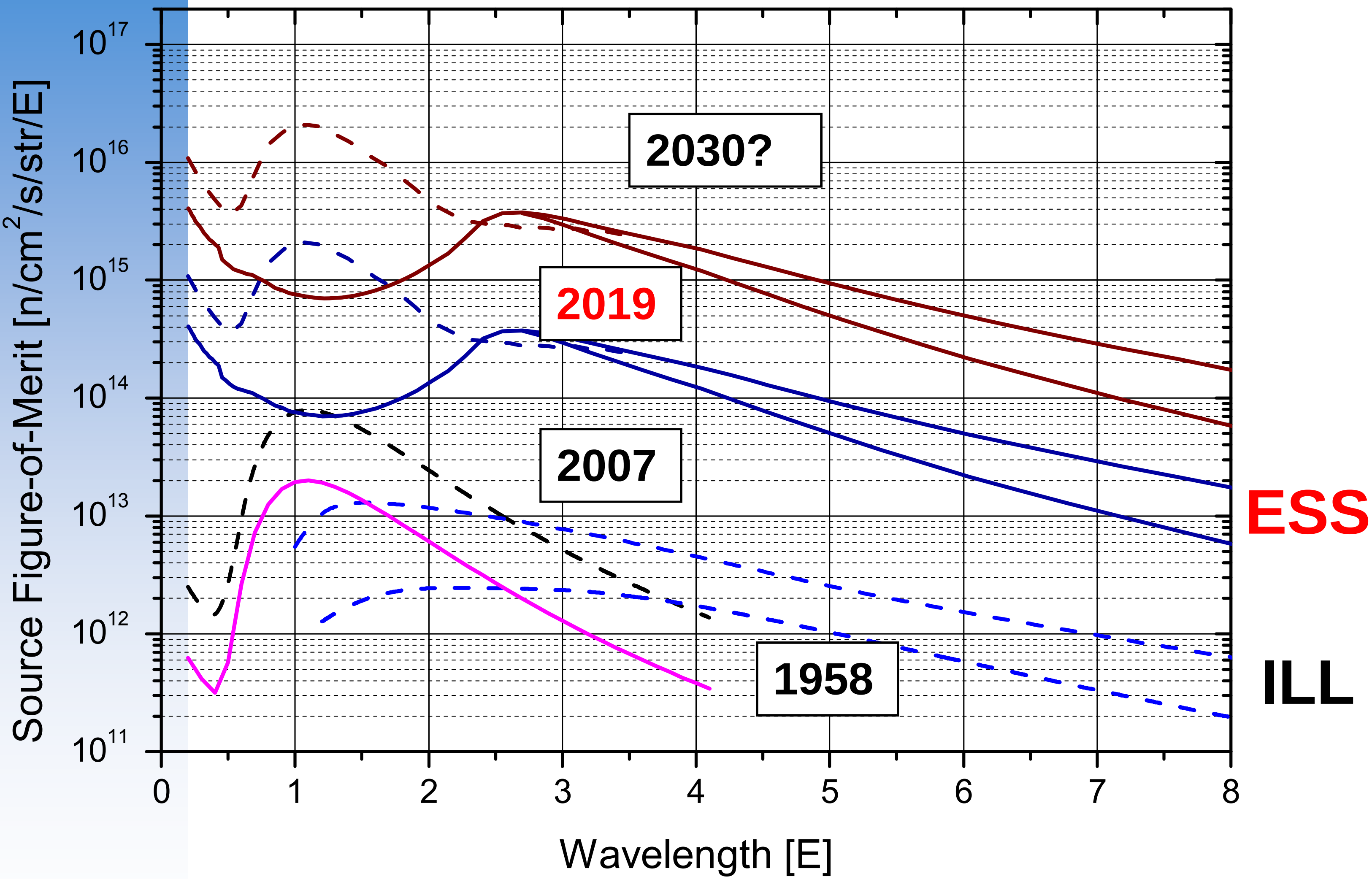
Reduced complexity

⇨ Leap in cold neutron performance at very favorable costs

ESS (5 MW LP):

- Construction costs comparable to SNS and J-PARC
- Operational costs comparable to ILL (36 MW vs. 70 MW!)
- Many beam lines possible with long guides (similar to continuous sources)
- High power consumption efficiency of linear accelerators
- No alternative technology in sight to be available within decades
- A new approach with large long term development potentials and perspectives: 30 MW? 100 MW?

Longer term perspectives:



Technical basis

- ESS reference design 2003 for LP target station
  - fully validated by SNS experience (incl. each component)
  - no major innovation proposed since
  - no substantially different new approach in sight
- Optimization of reference design: major effort > 30 M€ to consider all aspects and complexity (e.g. change of final proton energy → changes in proton current, radiation damage, target vessel life time, …)
- From reference design to optimized engineering design: collective effort by Pan-European ESS team and collaboration partners; subject to international review and common decision making process by ESS partners
- Accumulated new experience will need careful analysis in the framework of optimization effort (E.g. at SNS some built in linac features – couplers, piezo cavity compensation – are not used. Can they be left out?)

Main technical issues for engineering design

- **Linac frequency, accelerating gradient, possible design simplifications, final energy, upgradeability**
- **Choice of target, incl. upgradeability: mercury? Liquid lead or lead-bismuth? Rotating solid target wheel? (some R&D)**
- **If other than mercury proves to be favored, substantial R&D need will occur (cf. SNS switch to superconducting linac)**

Instrumentation

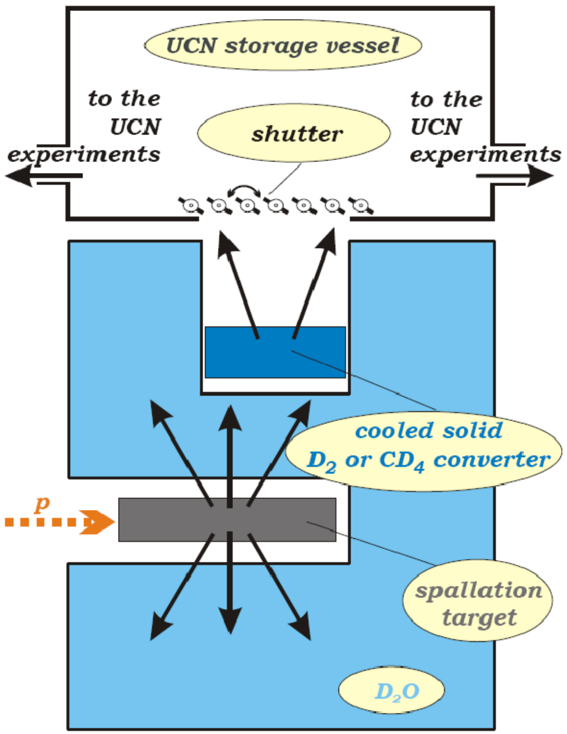
- Catalyze global development in collaboration with leading sources and teams.

  ILL, ISIS, SNS, J-PARC, FRM-II, PNPI, JINR, …

- Select best state-of-the-art technology in view of the latest scientific needs… as late as possible: from ~ 2013

UCN factory at ESS

opportunity 3 - 4 orders of magnitude higher UCN densities



Separate spallation target with solid cold source (**D_2** or **CD_4**) *A.Serebrov*

Shutter operation adapted to pulse structure *H.Rauch*

Maximum gain at low repetition rates
ESS: 16.67 Hz *Yu. Pokotilovski*

Summary

- **ESS: why?**
- **How?**
- **Why in Debrecen?**

Summary of conditions / advantages

- ESS: Pan-European project, Pan-European control, best possible Pan-European team
- Debrecen offers outstanding, dynamically developing academic, research, cultural, industrial, workforce, educational and quality of life environment.
- Rich Hungarian tradition in neutron science: BNC active user facility, Hungarian discoveries (Neutron Spin Echo, Supermirrors, Neutron holography, Long pulse neutron sources....)
- Well established and continuing tradition in nuclear industry, nuclear safety and regulatory environment
- Good geographical and geological conditions (site preparation similar to SNS)

Site selection

CITY OF **DEBRECEN**

- **The second largest city in Hungary in a region dynamically developing, main beneficiary of EU stuctural funds.**
- **Access: airport, motorway, train**
- **Scientific centre: University (30000 students), ATOMKI, high added value indutry**
- **Rich cultural life and a wealth of hospitality**

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ESS in Hungary:
(would be) the best choice for Europe

Thank you for attantion!