European Spallation Source: Status, Principles, Perspectives

UCANS V, May 2015

F. Mezei
Technical Coordinator

www.europeanspallationsource.se

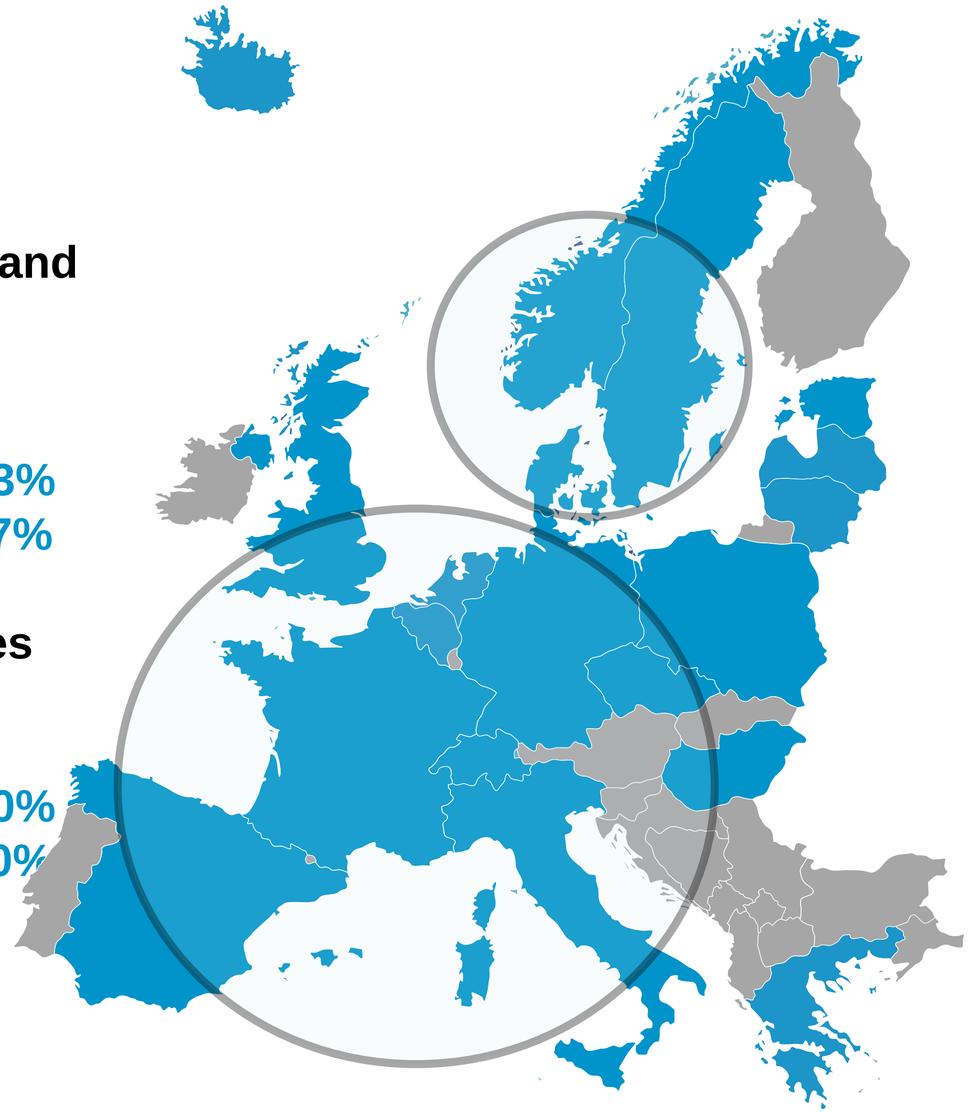
Financing includes cash and deliverables

Host Countries of Sweden and Denmark

- 47,5% Construction
- 15% Operations
- **In-kind Deliverables ~3%**
- **Cash Investment ~97%**

Non Host Member Countries

- 52,5% Construction
- 85% Operations
- **In-kind Deliverables ~ 70%**
- **Cash Investment ~ 30%**



Ground Break and Foundation Stone Celebrations

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Ground Break Event

- 2 September 2014 (200 guests)
- Hosted by Danish Minister for Science and Higher Education and Swedish Minister of Education and Research
- Recognized progress with member country commitments
- Official start of the construction!

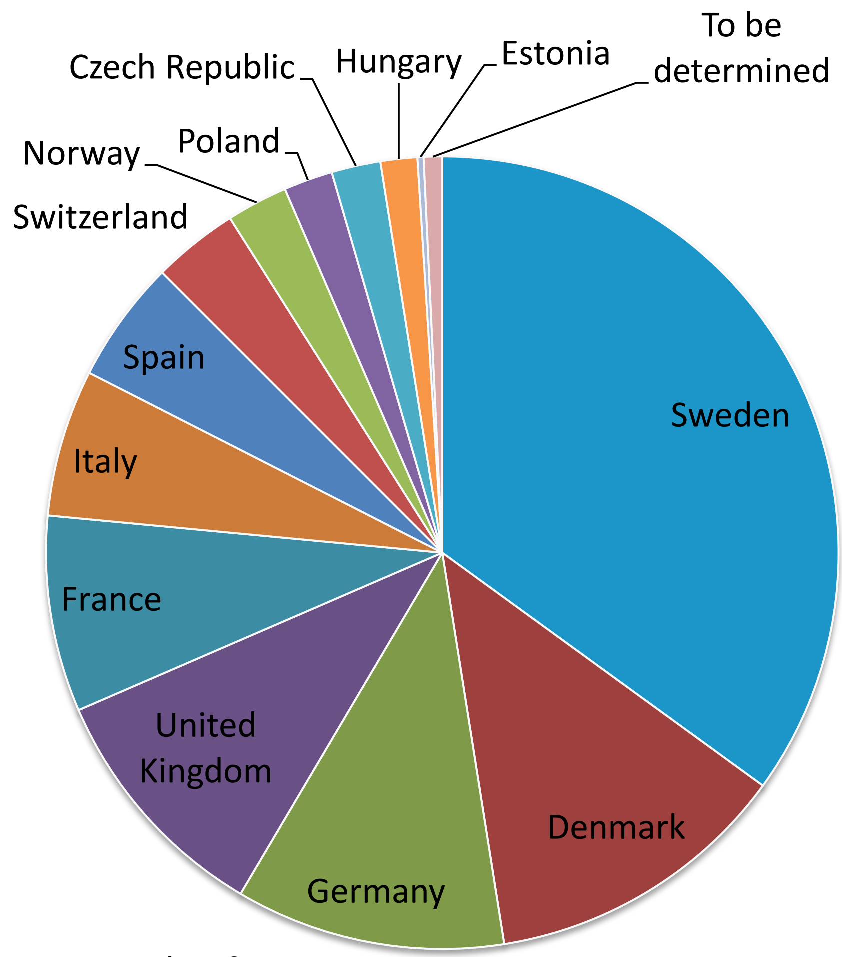
Foundation Stone Ceremony

- 9 October 2014 (700 guests)
- Programme on site including speeches, partner video, walking tour and reception
- Science Symposium in Lund
- Mobilized partners and stakeholders for construction!

Construction investment

Sweden	**35.0 %**
Denmark *	**12.5 %**
Germany *	**11.0 %**
United Kingdom	**10.0 %**
France	**8.0 %**
Italy	**6.0 %**
Spain *	**5.0 %**
Switzerland	**3.5 %**
Norway	**2.5 %**
Poland	**2.0 %**
Czech Republic	**2.0 %**
Hungary	**1.5 %**
Estonia	**0.25 %**
Total	**99.25 %**
Iceland	*tbd (0.25)*
Latvia	*tbd (0.25)*
Lithuania	*tbd (0.25)*
Netherlands	*tbd (2.0)*
Belgium	*tbd (2.0)*
Greece	*tbd (1.0)*

➢ **0.75 %**



* Includes Pre-construction Costs

ESS construction cost baseline

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Millions Euro (Jan 2013 pricing)	
Conventional Facilities	531,9
CF scope supported by host countries	-93,0
Accelerator Systems	510,2
Target Systems	155,2
Integrated Control System	73,0
Design & Engineering	33,7
Neutron Scattering Systems	350,0
Project Support & Administration and Licensing	123,8
Contingency	158,2
Total Construction Budget and ESS Cost Book Value	**1843,0**

ESS site: artists's perception

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ESS site: current drone view (changing)

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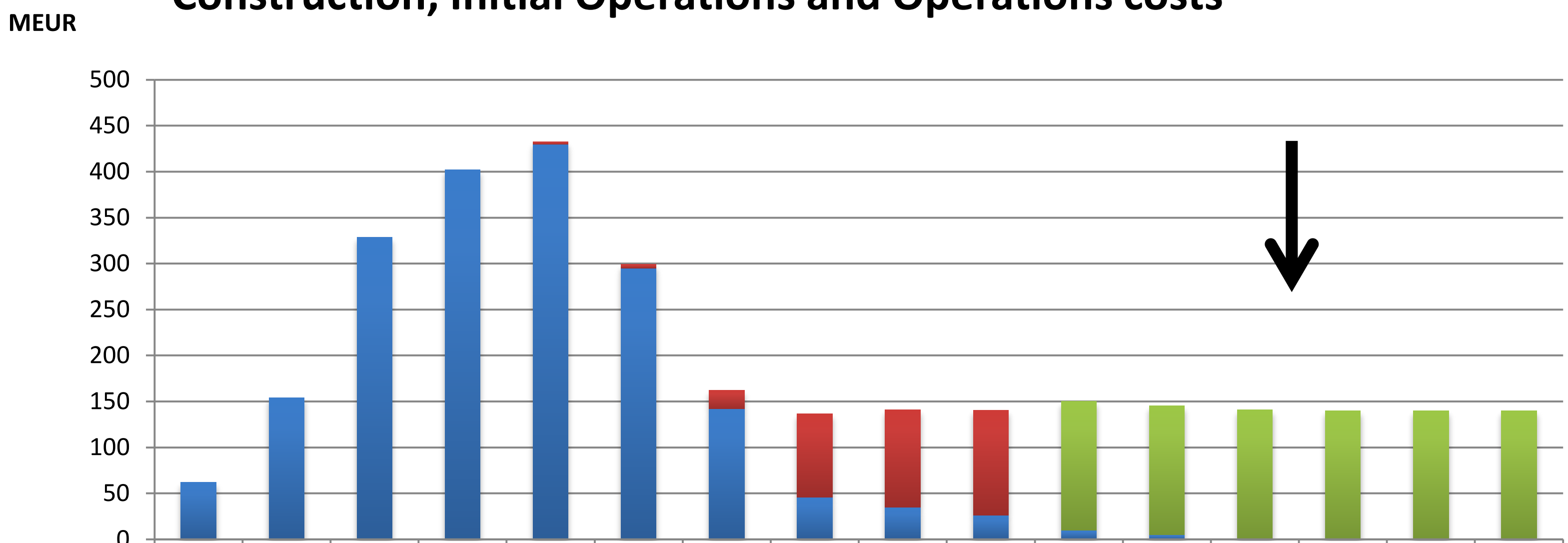
Planning & budget

Construction, Initial Operations and Operations costs

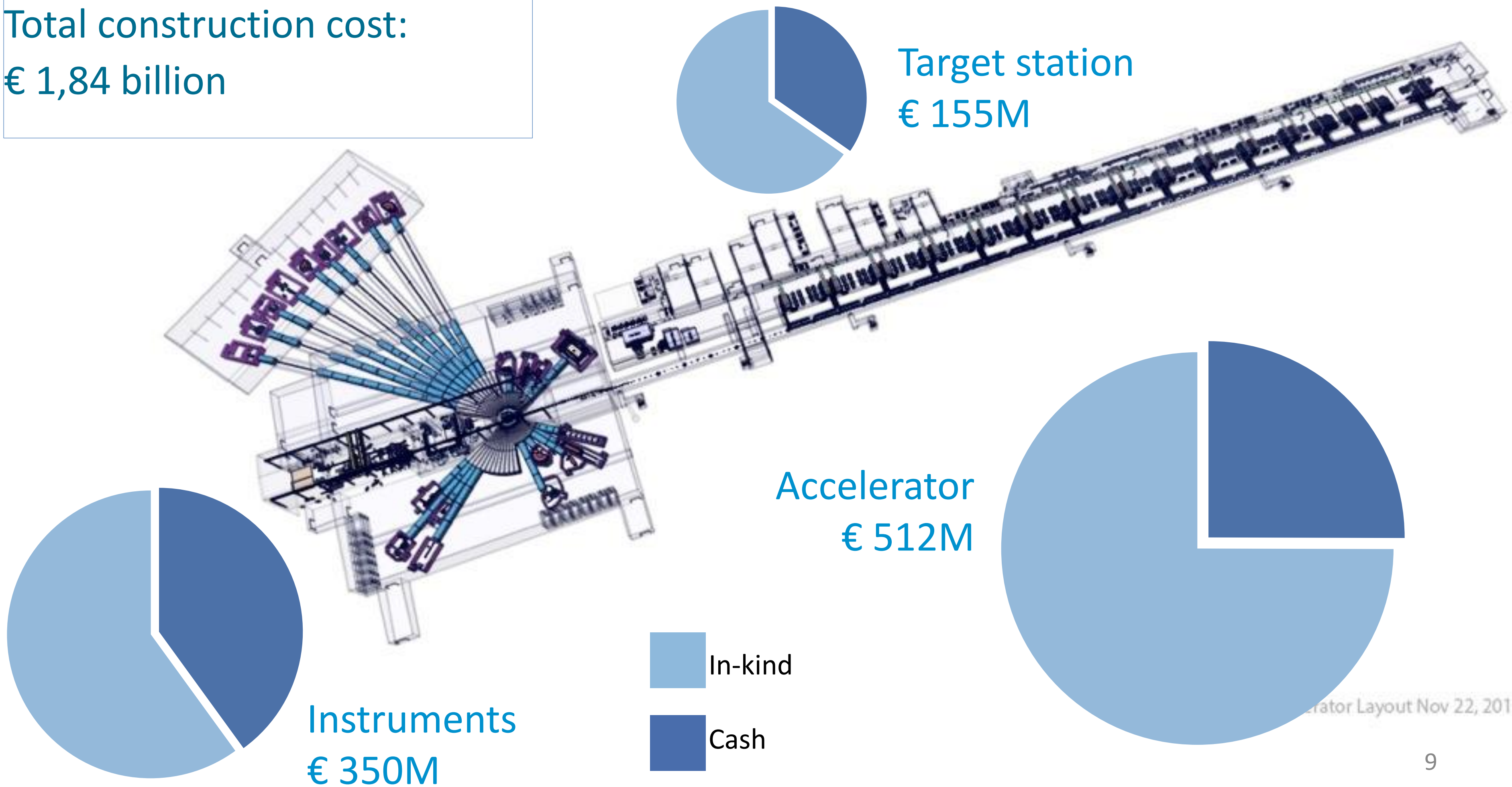


	2013	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028
Operations (steady state)											140	140	140	140	140	140
Initial Operations					3	4	21	91	106	115						
Construction	62	154	329	402	429	295	142	46	35	26	10	5	1			

Planning & Budget & In-kind potential

Total construction cost:

€ 1,84 billion



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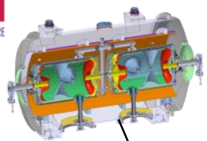
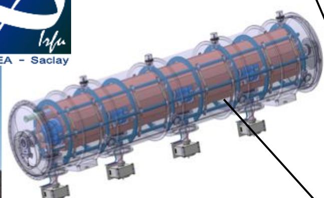
ESS: a broad collaboration

IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY



CEA - Saclay

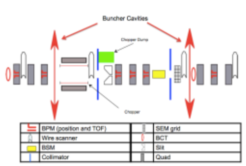


Pierre Bosland

CERN

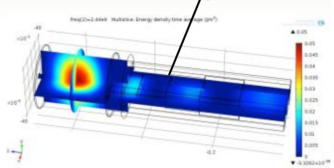
CERN

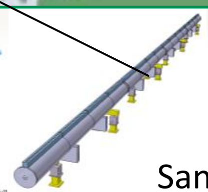
Roger Barlow



Ibon Bustinduy

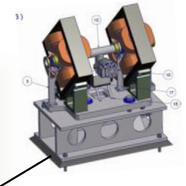
ESS bilbao





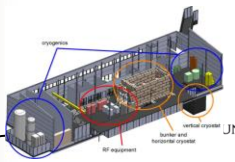
Santo Gammino

INFN Istituto Nazionale di Fisica Nucleare



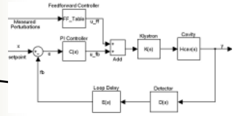
ISA

Søren Pape Møller



UPPSALA UNIVERSITET

Roger Ruber



LUNDS UNIVERSITET

Anders J Johansson

The National Center for Nuclear Research, Swierk

ESS: a broad collaboration

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Helmholtz-Zentrum Geesthacht

AARHUS UNIVERSITY

DTU

IFE

UPPSALA UNIVERSITET

TU Delft Technische Universiteit Delft

ISIS

LINKÖPINGS UNIVERSITET

JÜLICH FORSCHUNGSZENTRUM

LUND UNIVERSITY Faculty of Science

Nuclear Physics Institute of the ASCR public research institution

Orphée Laboratoire Léon Brillouin

TECHNISCHE UNIVERSITÄT MÜNCHEN

PAUL SCHERRER INSTITUT PSI

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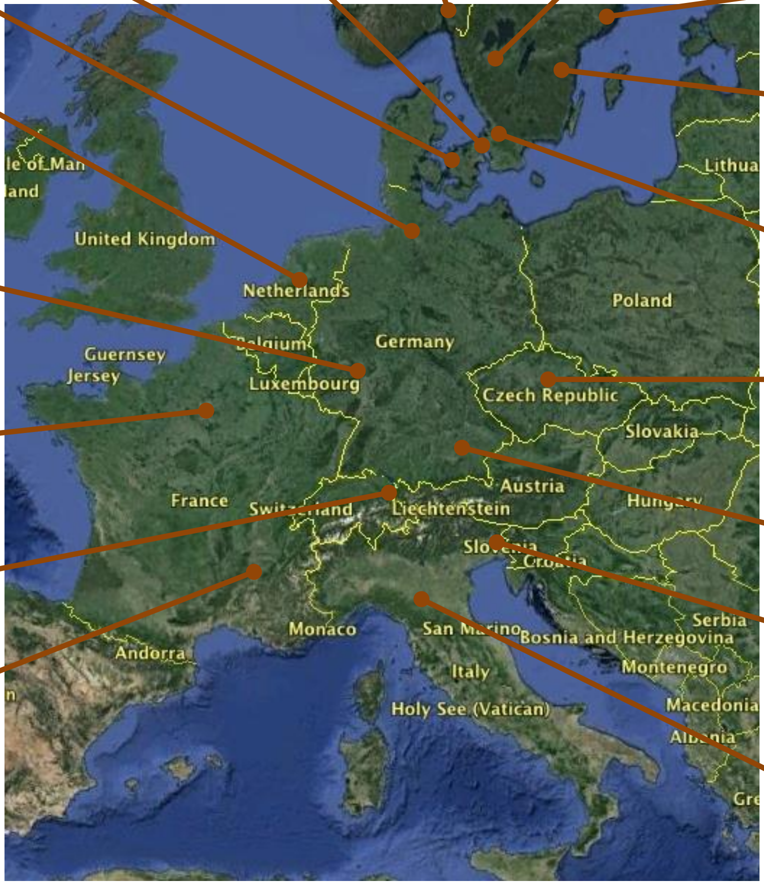
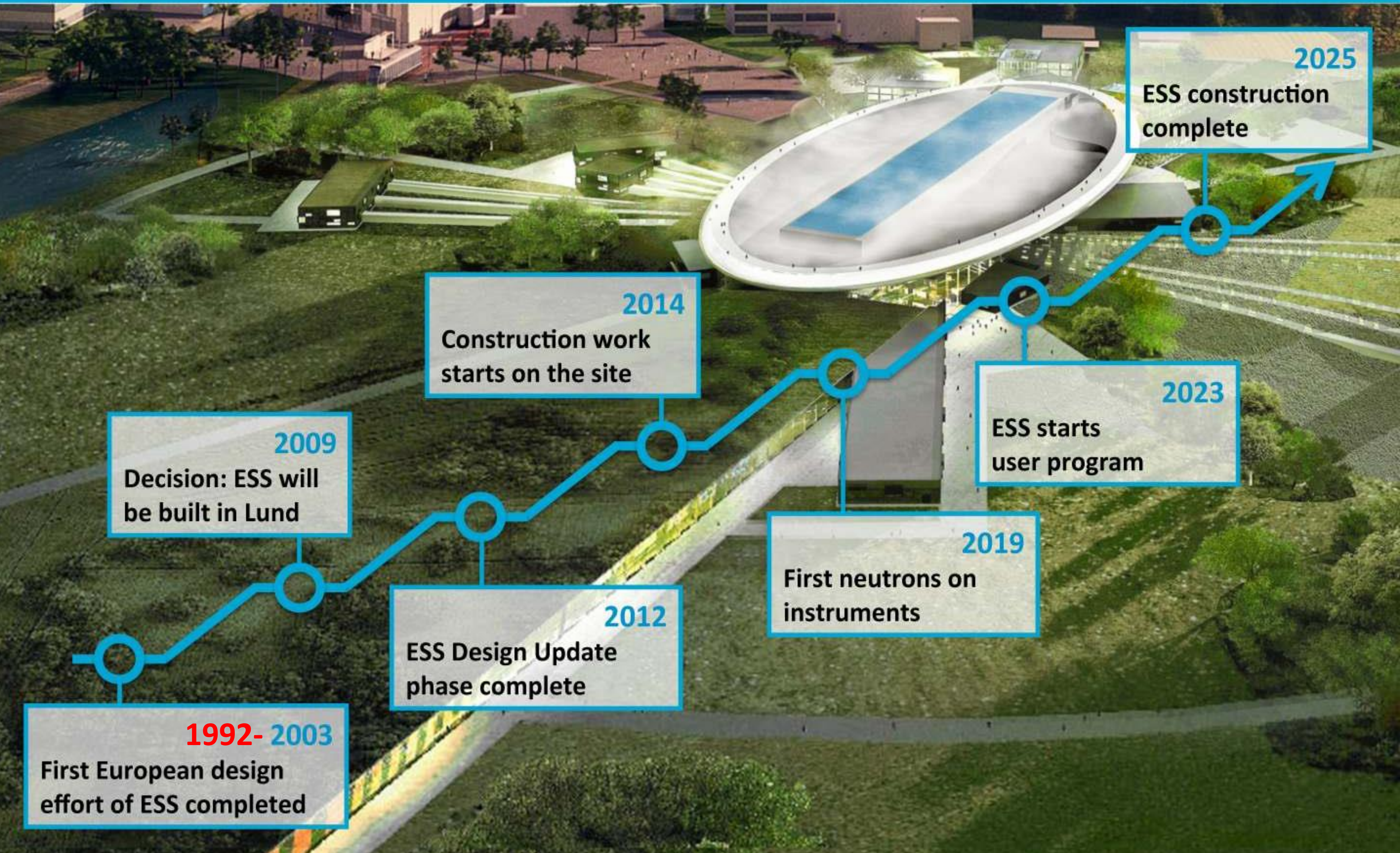


Road to realizing ESS



Evolution of ESS plans

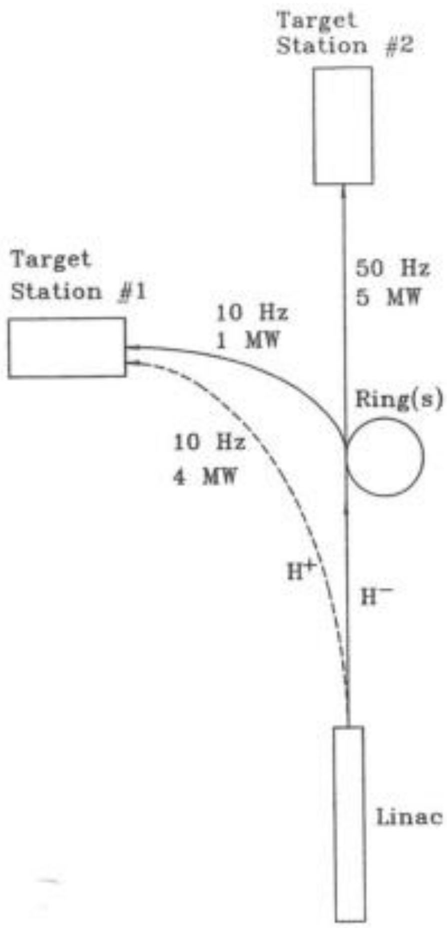


Fig. 5. A combination of the short and long pulse spallation approach proposed to optimize efficiency over the whole spectrum of applications.

(Mezei, 1994)

1992: 100 kJ short pulses, two target stations

1993: add 400 kJ long pulses

2006: ESFRI road map call: one target station, long pulses, 5 MW

Neutron generation:
energy $\rightarrow$ atomic nuclei

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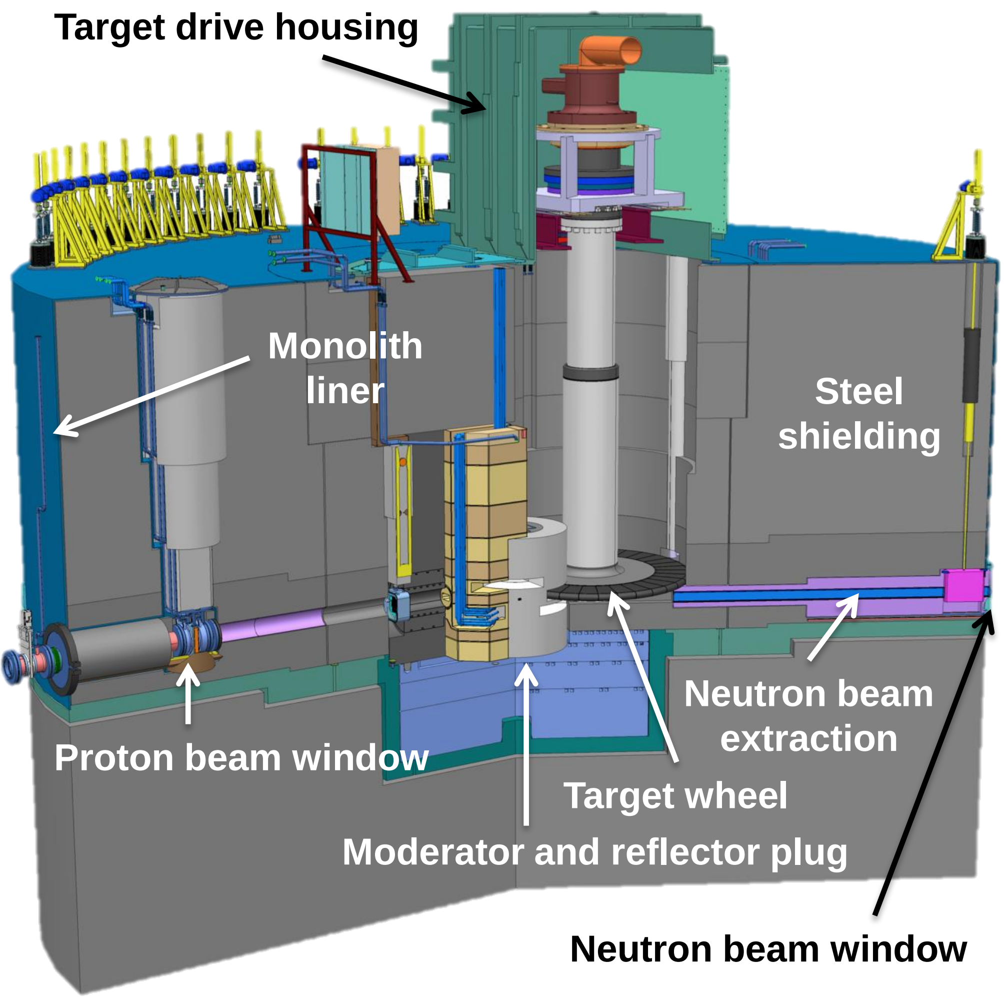
Fast neutrons produced / joule heat deposited:

Fission reactors:	$\sim 10^9$	(in ~ 50 liter volume)
→ Spallation: (US patent: from Leningrad ~1970)	$\sim 10^{10}$	(in ~ 2 liter volume)
Fusion:	$\sim 1.5\text{x}10^{10}$	(in ~ 2 liter volume)
(but neutron slowing down efficiency reduced by ~20 times)		
Photo neutrons:	$\sim 10^9$	(in ~ 0.01 liter volume)
→ Nuclear reaction (p, Be):	$\sim 10^8$	(in ~ 0.001 liter volume)
Laser induced fusion:	$\sim 10^4$	(in ~ 10^{-9} liter volume)

Spallation: most favorable for the foreseeable future (neutrons/€)
Compact source: lowest cost / facility

Slow neutron generation: target monolith



Functions:

- Convert protons to neutrons
- Heat removal
- Confinement and shielding

Unique features:

- Rotating target
- He-cooled W target

Current highest power neutron sources

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SNS (Oak Ridge, USA)

J-PARC (Tokai Japan)

Pulsed source: better neutron efficiency

(First pulsed source: Dubna, 1960's)

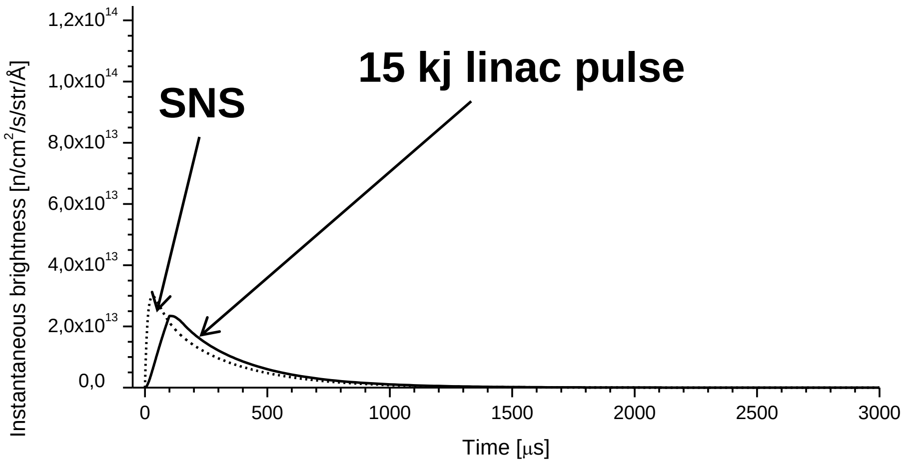
Instantaneous power on target (e.g. 1 MW at 60 Hz, i.e. 17 kj in ~1 μs pulses on target): **17 x**

→ **Pressure wave: 300 bar**

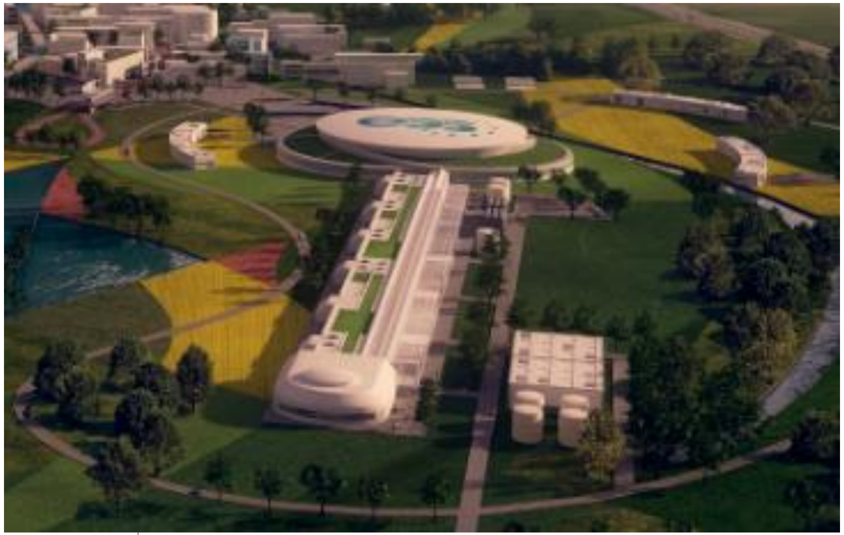
Reaches limits of technology

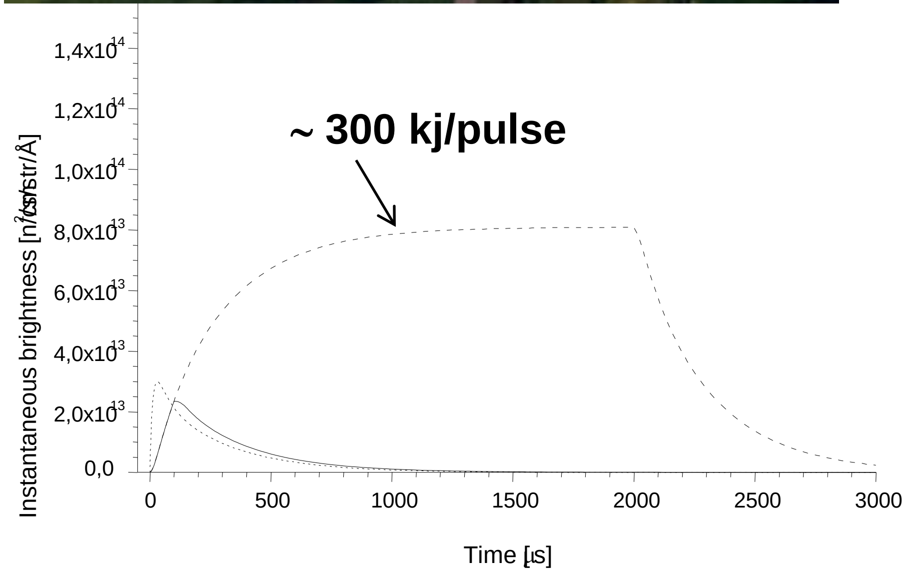
Improving efficiency on green field

But:
Cost equivalent linear accelerator alone can produce the same **cold neutron pulses by ~100 μs proton pulses at ~ 0.15 GW instantaneous power: 2 x ILL**



Next generation: long pulses





Cost equivalent linear accelerator alone can produce the same cold neutron pulses **by ~100 μs proton pulses at ~ 0.15 GW instantaneous power** → Leave the linac on for **more neutrons per pulse and higher peak brightness…**

Next generation: long pulses

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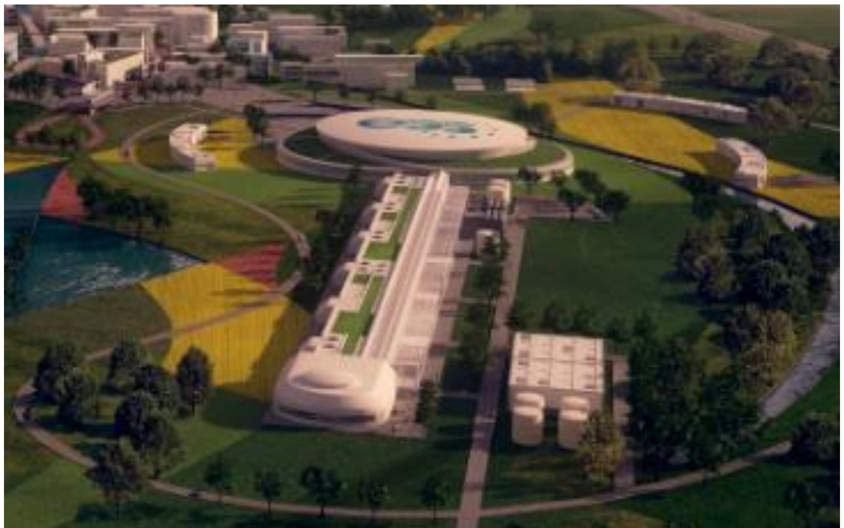

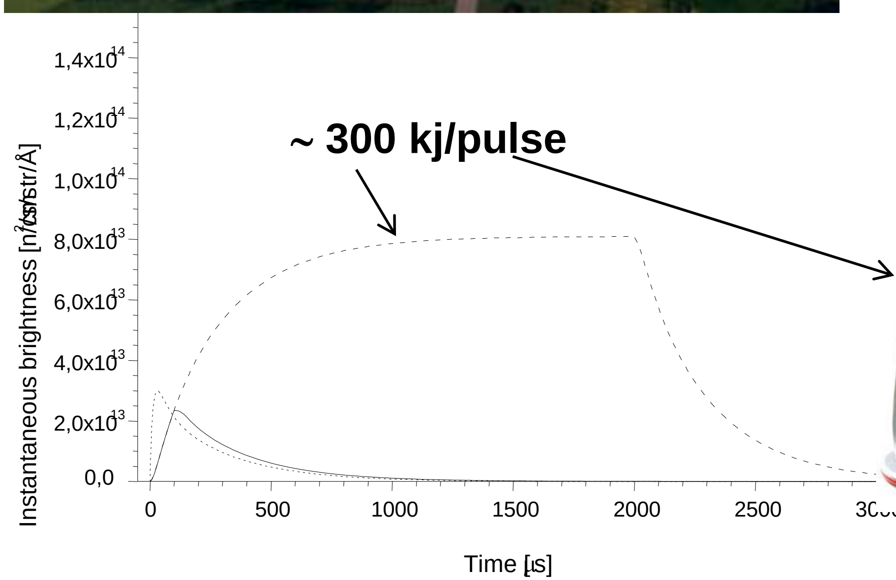

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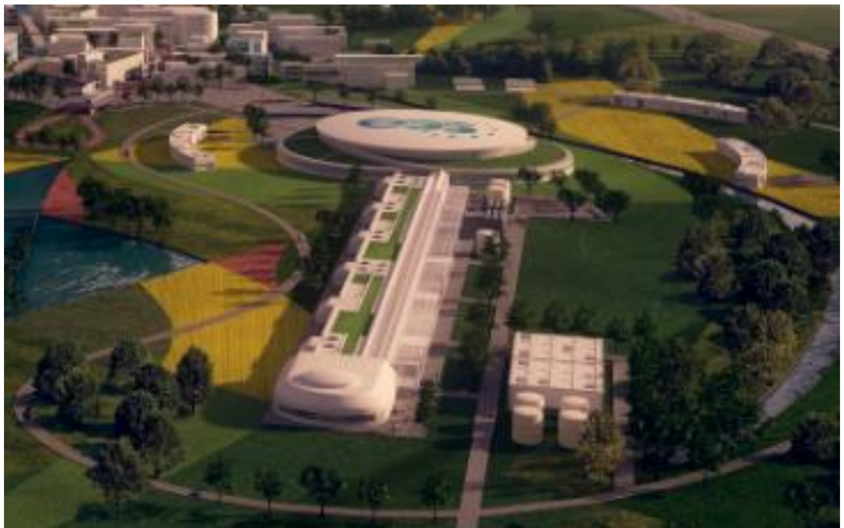

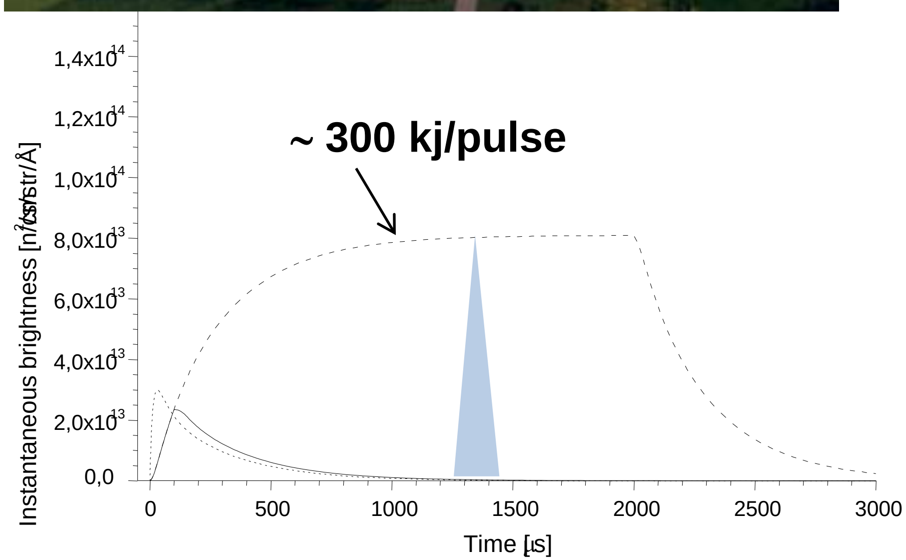

Cost equivalent linear accelerator alone can produce the same cold neutron pulses **by ~100 µs proton pulses at ~ 0.15 GW instantaneous power** → Leave the linac on for **more neutrons per pulse and higher peak brightness…** and use mechanical pulse shaping

→ **Long Pulse source**

Next generation: long pulses

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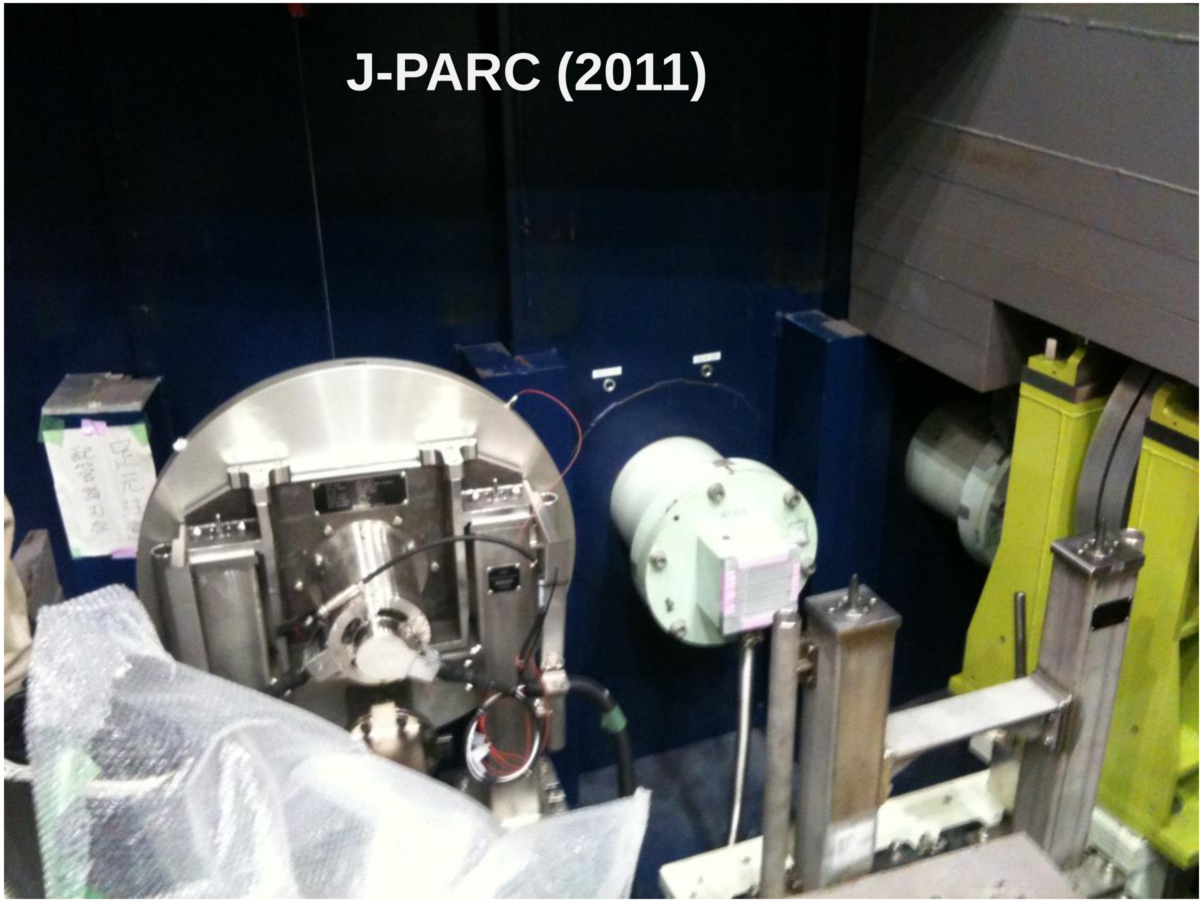
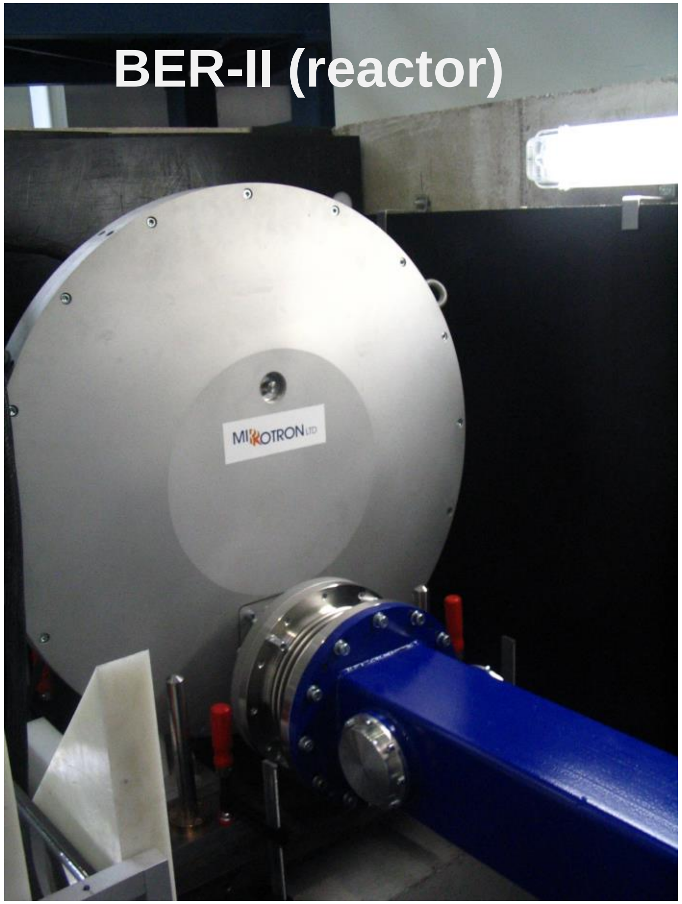
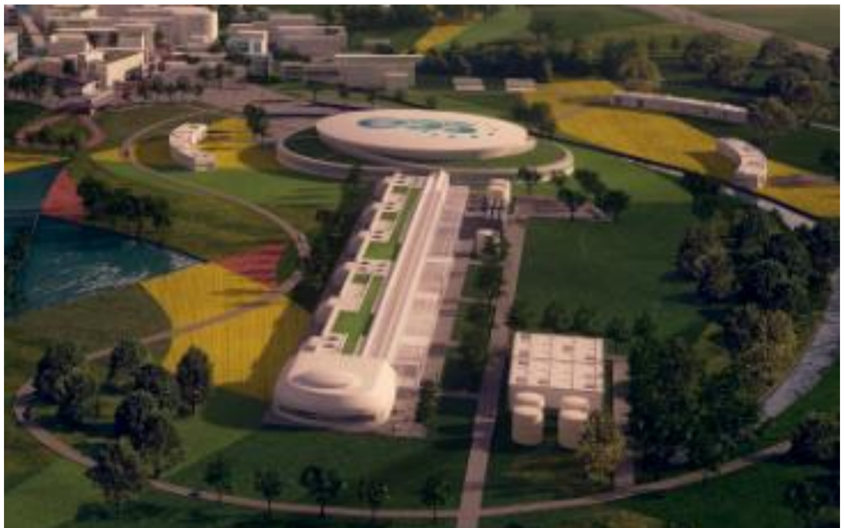
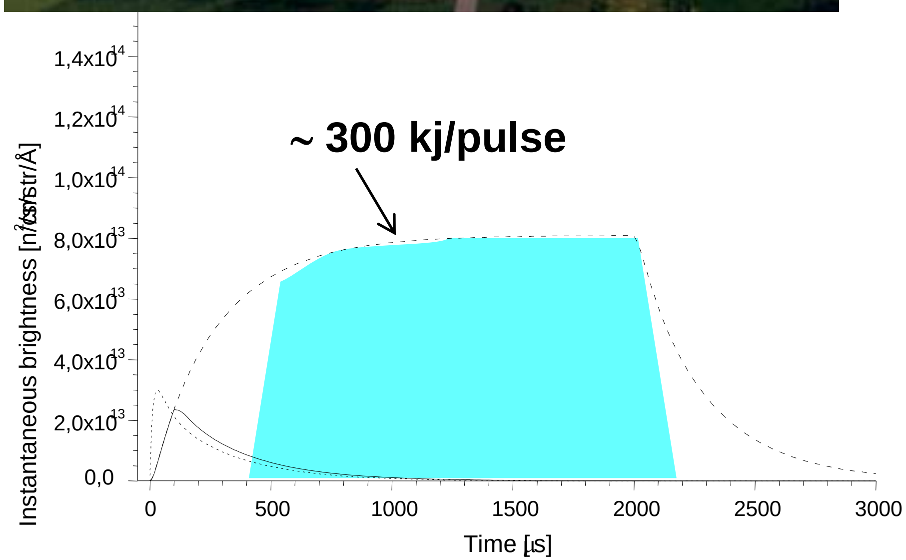
Neutron beams with mechanical choppers (since Fermi, 1940s)





Next generation: long pulses





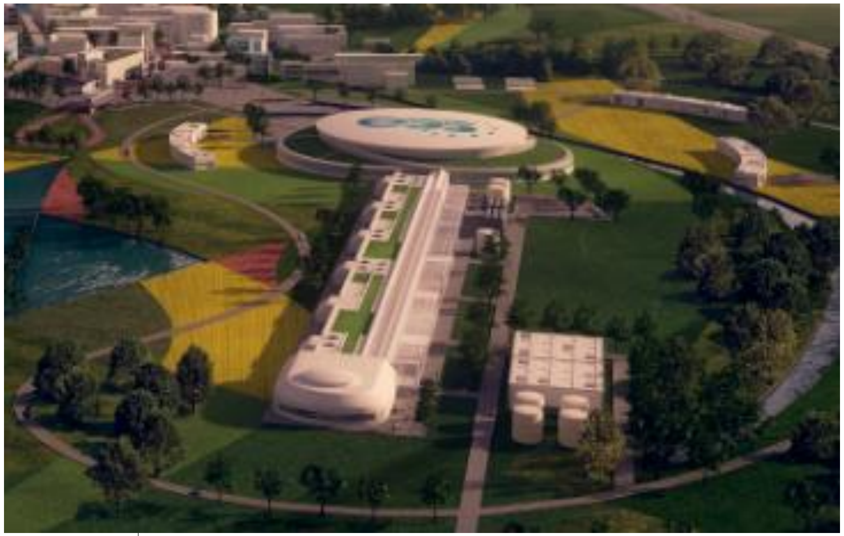
Cost equivalent linear accelerator alone can produce the same cold neutron pulses **by ~100 μs proton pulses at ~ 0.15 GW instantaneous power** → Leave the linac on for **more neutrons per pulse and higher peak brightness…** and use mechanical pulse shaping

→ **Long Pulse source**

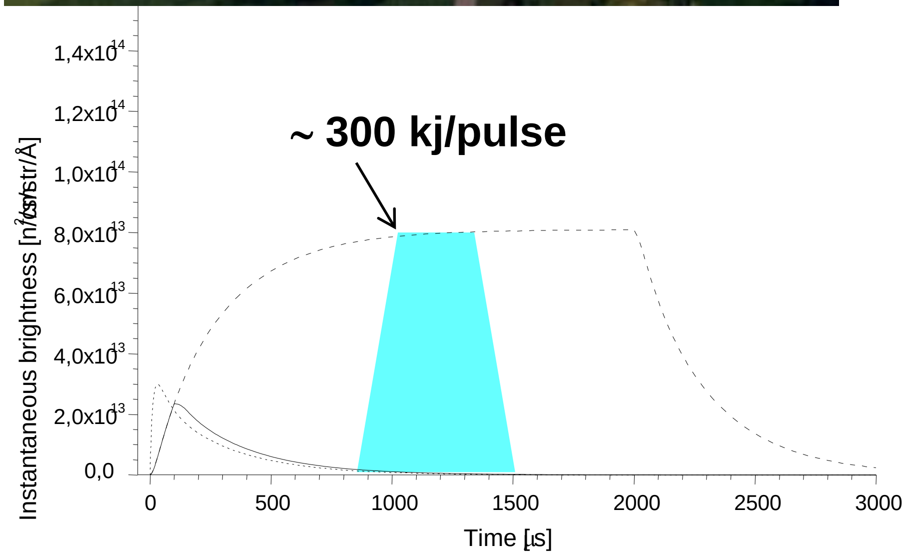
ESS: 5 MW accelerator power

→ **more neutrons for the same costs and at reduced complexity**

Next generation: long pulses



≈ 10 MW



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→ **Long Pulse source**

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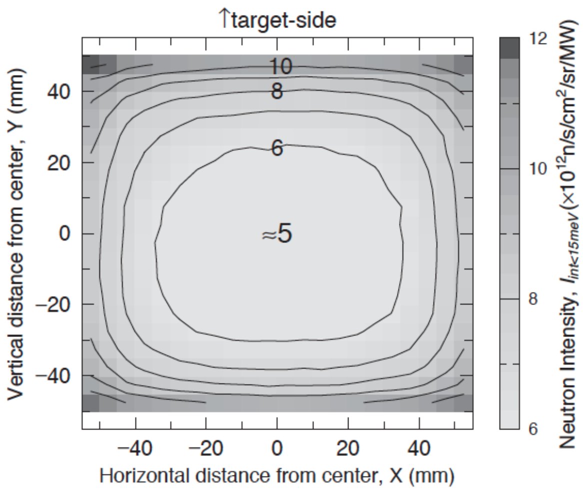
Moderator optimization: from conventional to low dimensional

J-PARC innovation: para-H_2 coupled volume moderator

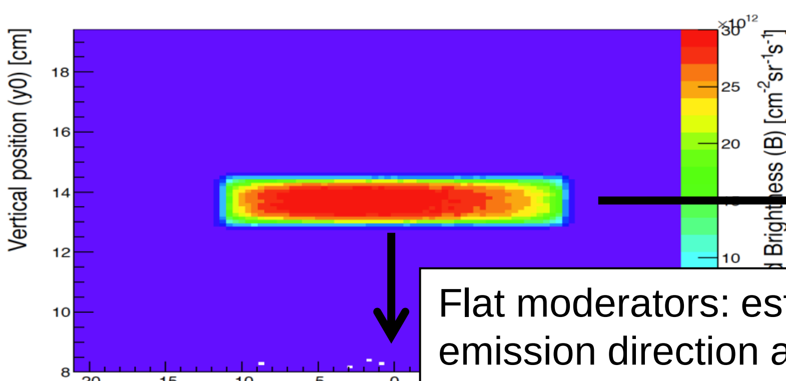


(Kai et al, J-PARC 2004)

Thermal neutrons arriving from the surroundings are transformed into cold ones within about 1 cm of the walls of the moderator vessel

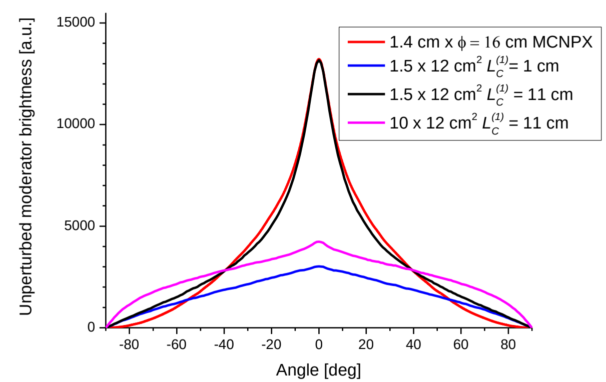
Cold neutron mean free path: ~11 cm in para-H_2

Low dimensional moderator:
directional emission along moderator walls



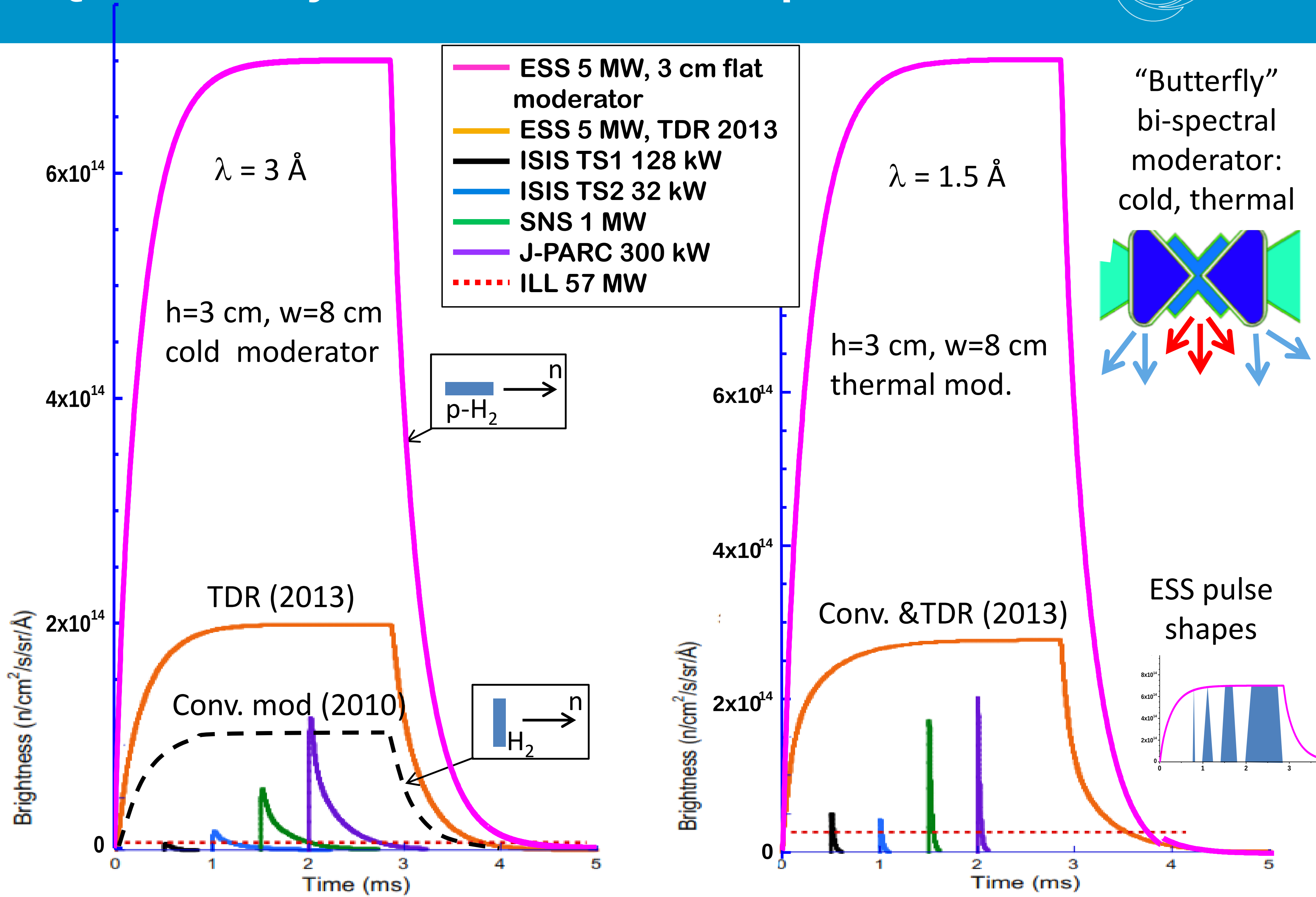
Direction of high bright-ness emission

Flat moderators: established practice with emission direction at 90° of preferential directions



(Mezei et al, 2014)

Qualitatively new level of beam performance



ESS: the next generation

- **Innovative use of established technologies:**
  - **high environmental safety**
  - **lower complexity, new power level is a challenge**
  - **comparable costs to SNS, J-PARC or ILL operations**
  - **order(s) of magnitude gain in intensity = sensitivity = capability**
- **Large in-kind fraction, green field site: large challenges**
- **High energy efficiency (35 MW vs. 70 MW at ILL)**
- **Perspectives of European neutron research facilities for ~6000 users:**
  synergetic use: high performance when needed / efficient

Total cost (M€)	Scenario	Capacity	Productivity (2030)	Productivity wrt current baseline
275	Current Baseline (major sources)	100%	400	1
378	ESS + All current major sources	116%	1240	3
298	ESS + ISIS + FRM-II + ILL	73%	1140	2.8
103	ESS Only	16%	280	0.7

See you there!   Thank you.