# ESS Target Facility Design

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# Outline

- Background
- Status of technical systems
- Project status and plans

# ESS will be the most powerful spallation source in the world

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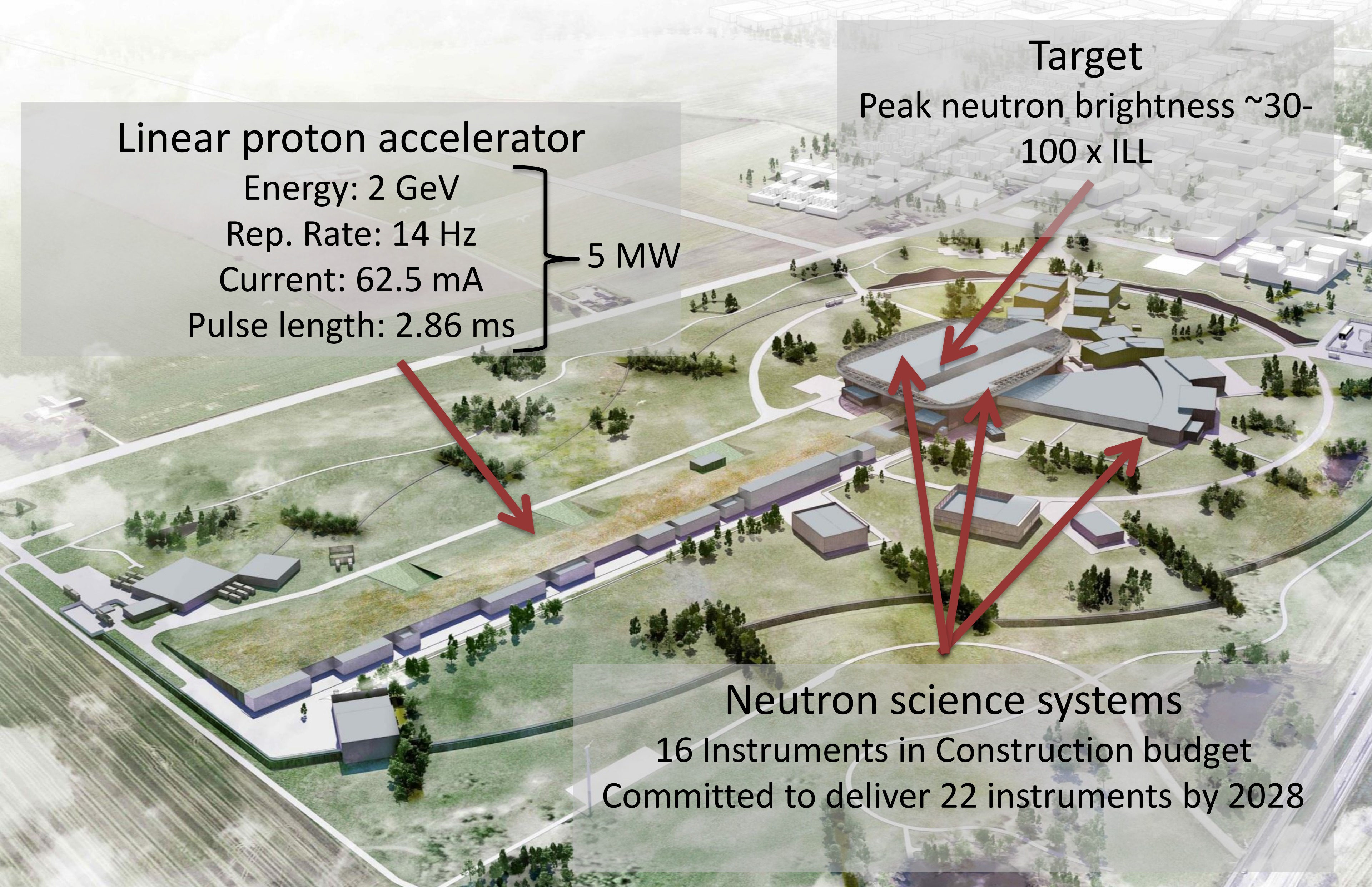


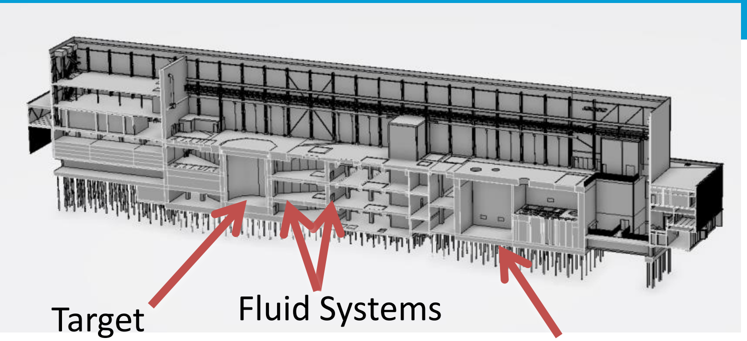
# ESS funding is in place and construction is underway

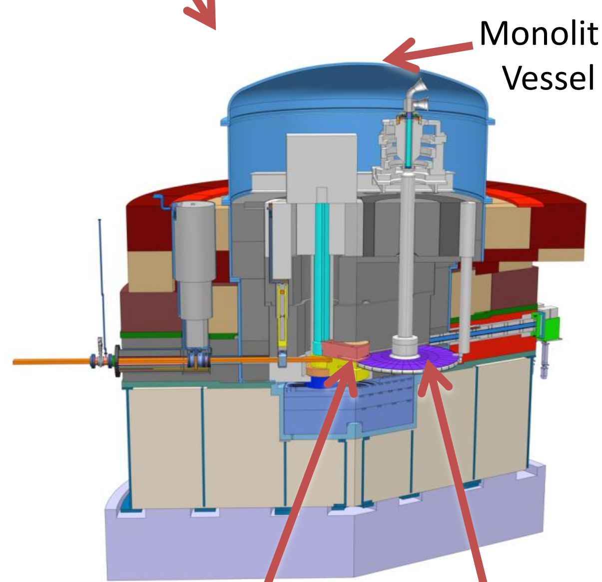
# Target Station functional requirements

- Convert protons to neutrons
- Remove heat – 5 MW
- Protect public, workers, and environment from radioactive hazard

# Selected technologies

- Convert protons to neutrons
  - Spallation source material – W
  - Liquid $H_2$ and $H_2O$ moderators + Be reflector convert neutrons to low energy
  - Neutron beam ports transport neutrons to instrument beam lines
- Remove heat deposited by 5 MW proton beam
  - He and water cooling systems
- Protect public, workers, and environment from radioactive hazard
  - Shielding allows hands-on access outside monolith
  - Fluid purification and ventilation systems control radioactive inventory
  - Remote Handling Systems provide capability to handle activated equipment
    - Remove/replace, store, and process for disposal spent targets, moderator/reflector plugs, proton beam windows, …
  - Safety-credited, active controls shut-off beam for certain off-normal conditions





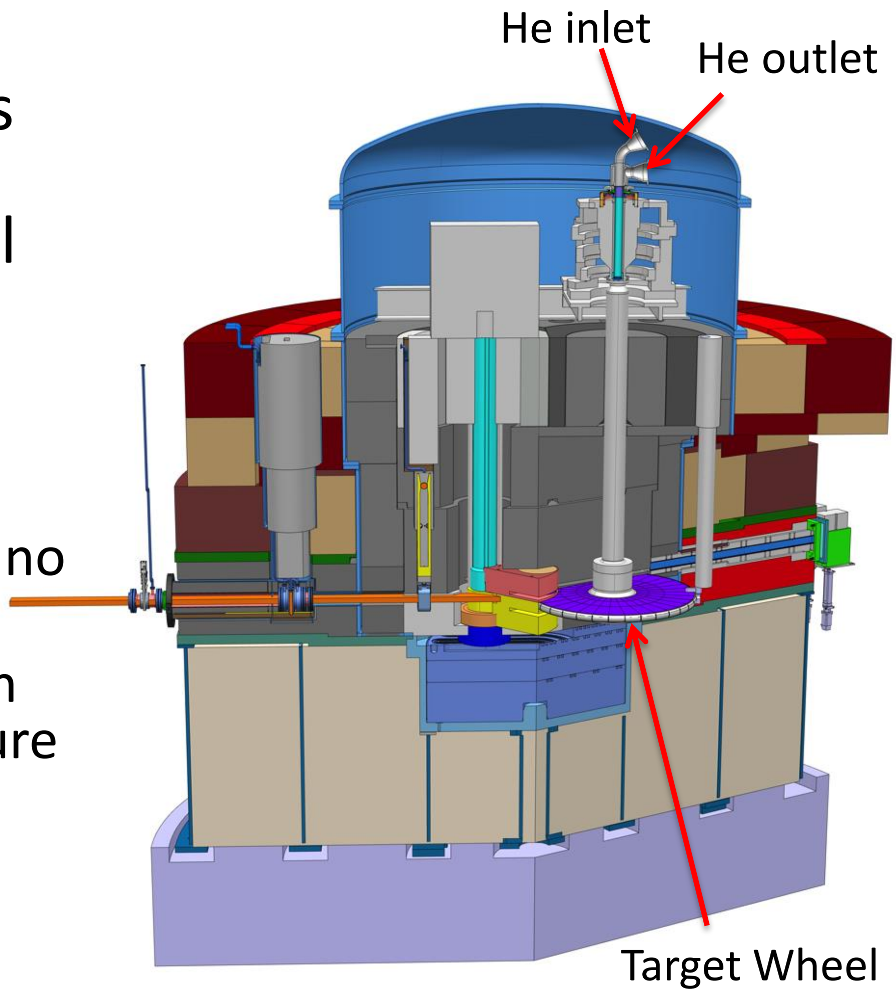
# Status of Target Project

- Most Target Station systems are nearing completion of preliminary design; some are in detailed design phase

- Major hardware systems will be provided as in-kind contributions
  - In-Kind partners selected for 8 of 25 Target Project systems
  - Partners for most of the remaining systems will be in place by the end of 2015

# Spallation Target is a Helium-Cooled Tungsten Wheel

- To handle the 5 MW proton beam power the target needs to be moving, e.g. flowing liquid metal or rotating wheel
  - ESS has chosen the rotating wheel concept based on its simplicity and long lifetime
  - Helium selected as coolant because of its inert nature and no phase change concerns
  - Tungsten chosen for its neutron production and high temperature capability
    - 60 n/p at 2 GeV



# Key parameters for Target Wheel

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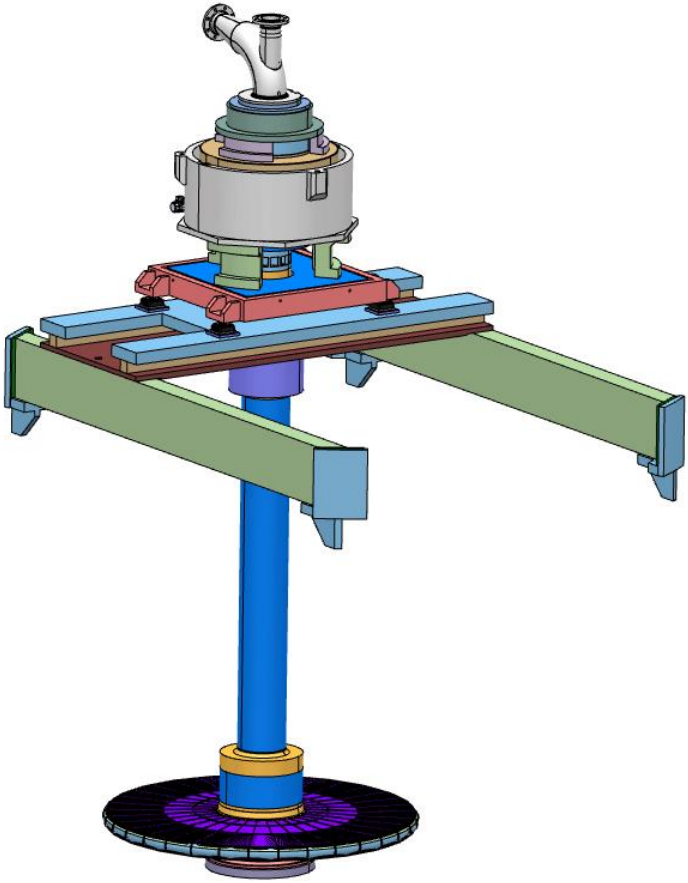
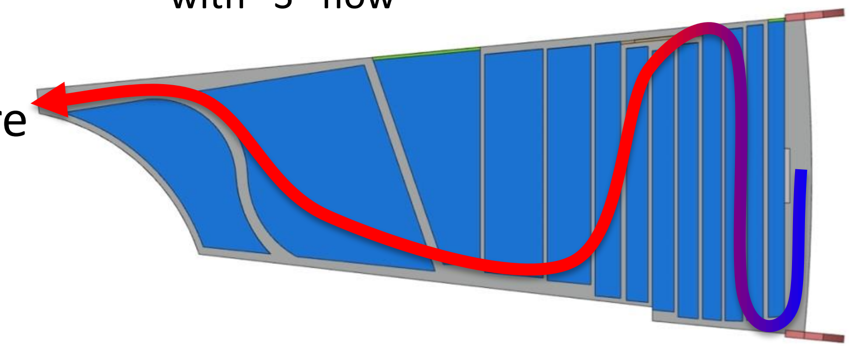
- Wheel diameter 2.5 m
- Shaft length > 5 m places drive unit far from high radiation region
- Tungsten bricks arranged in 36 sectors
- Rotational speed ~ 0.4 Hz
- Lifetime of 5 years at 5 MW based on radiation damage
  - 10 dpa damage to stainless steel vessel

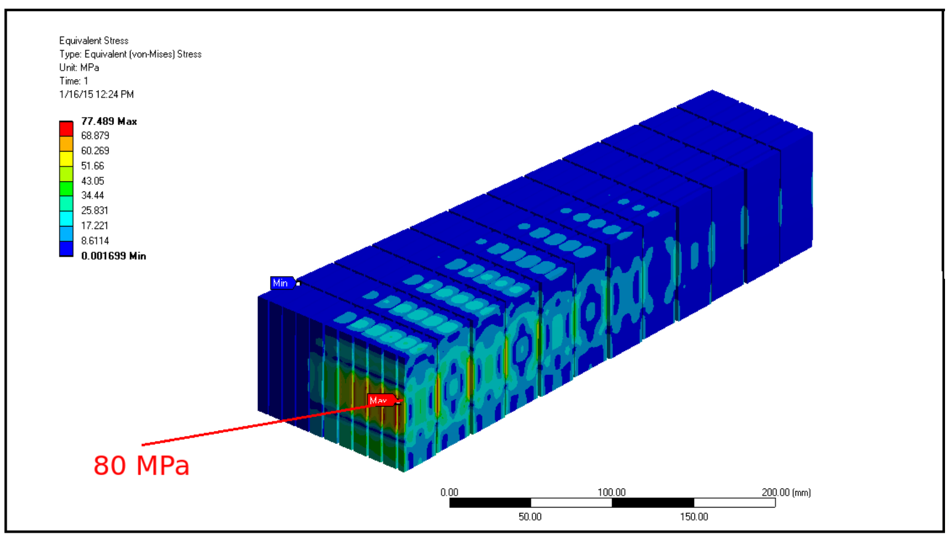


# Target wheel design concept finalized and detailed design underway

- ESS-Bilbao is our in-kind partner for the Target Wheel scope
  - New design concept is simpler, more manufacturable, and has lower temperatures and stresses
    - Tungsten stress < 100 MPa
    - Tungsten temp < 400 °C

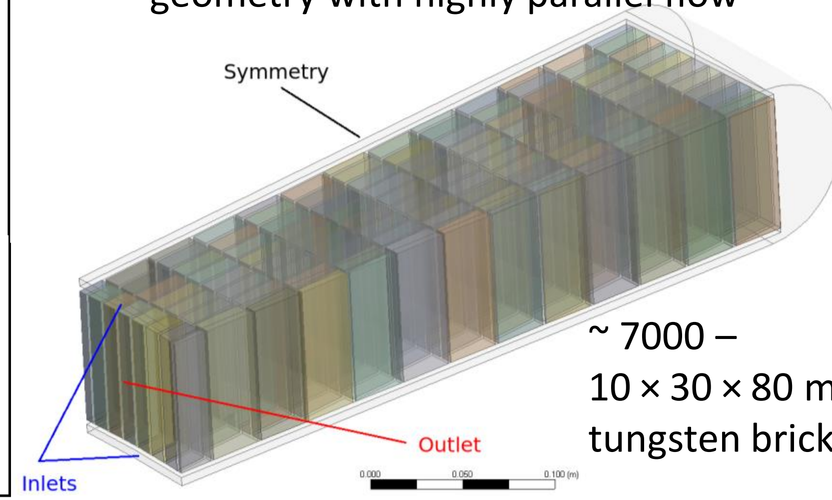
TDR design (2013): Plate geometry with "S" flow






Stress After a Pulse

New baseline design (2015): Brick geometry with highly parallel flow




~ 7000 – $10 \times 30 \times 80\ mm^3$ tungsten bricks

# Helium Cooling System Uses Standard Commercial Equipment

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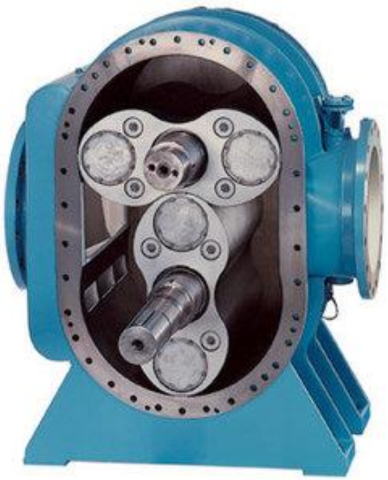
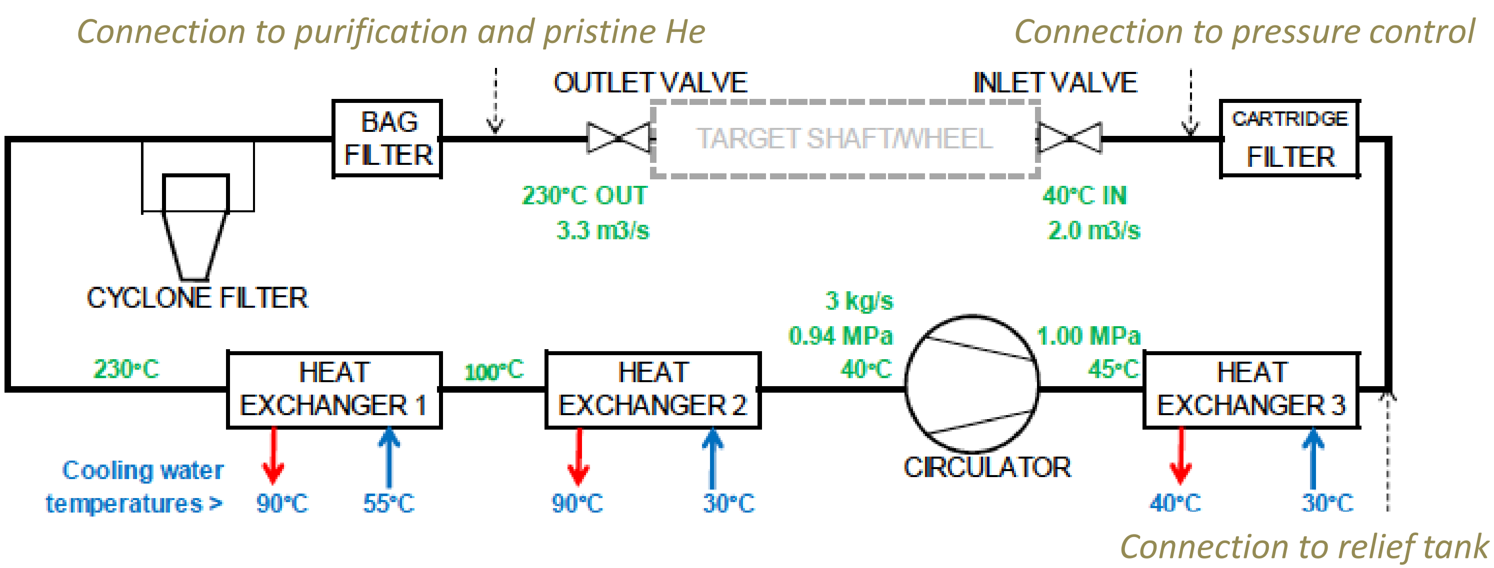
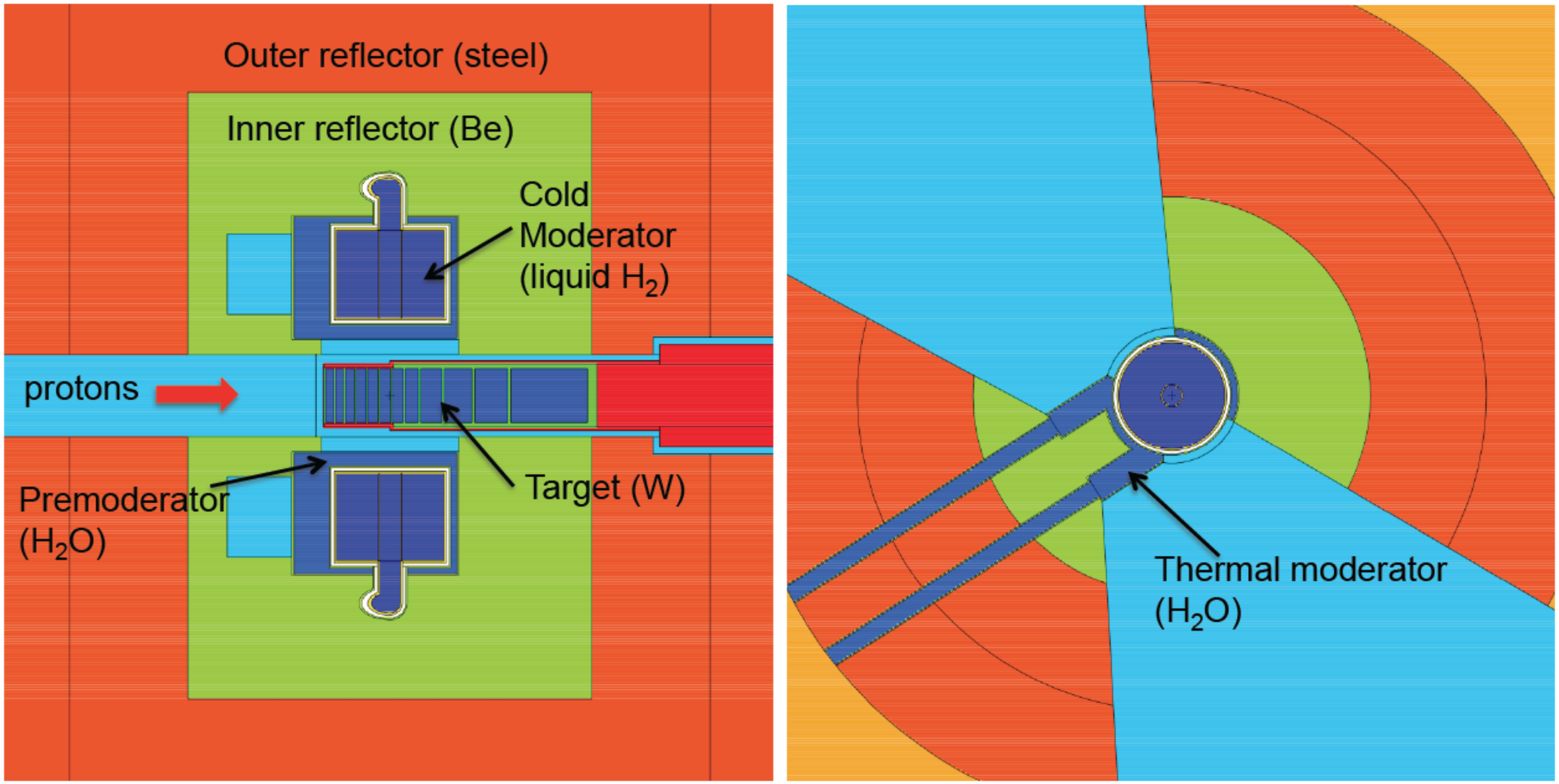
- Target He Cooling System parameters:
  - Mass flow 3 kg/s
  - Pressure 1.0 MPa
  - Inlet/outlet temperature 40/230 °C
- Change in He pressure from 3.5 (2013-TDR) to 10 bar (new baseline) allows use of commercial off-the-shelf process gas blowers as circulator
  - Robust, few rotating parts
  - Higher mechanical stresses on vessel and more He leakage, but well within allowable values





# TDR (2013) “Volume” Moderators




- Liquid $H_2$ for cold neutrons and water moderators for thermal neutrons
- Be reflector
- 2 x 60° viewing angle (not all instruments can view a given moderator)
- Top and bottom moderators identical
- Thermal moderator far from “hot spot”

# Moderator studies identified potential for huge increase in cold neutron brightness

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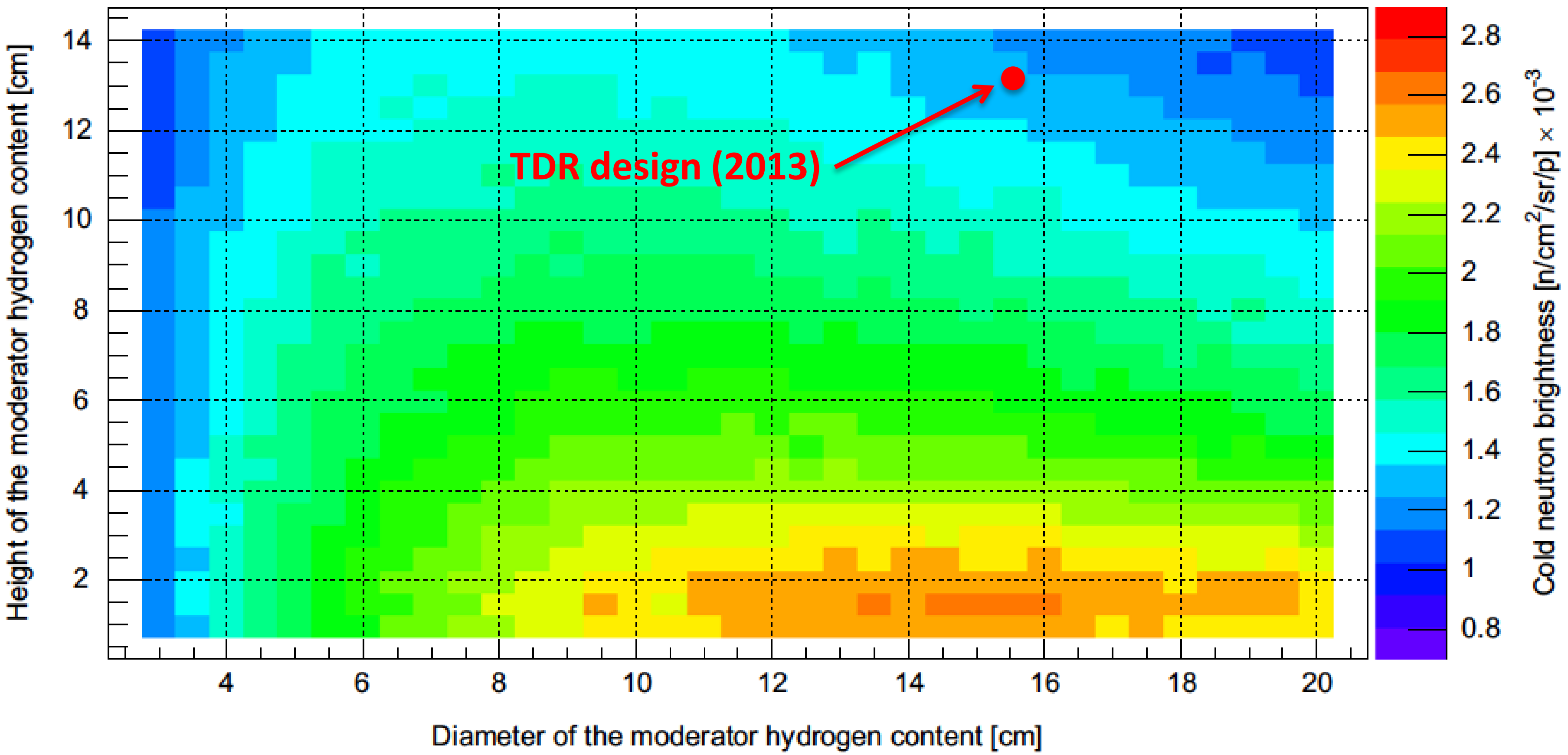
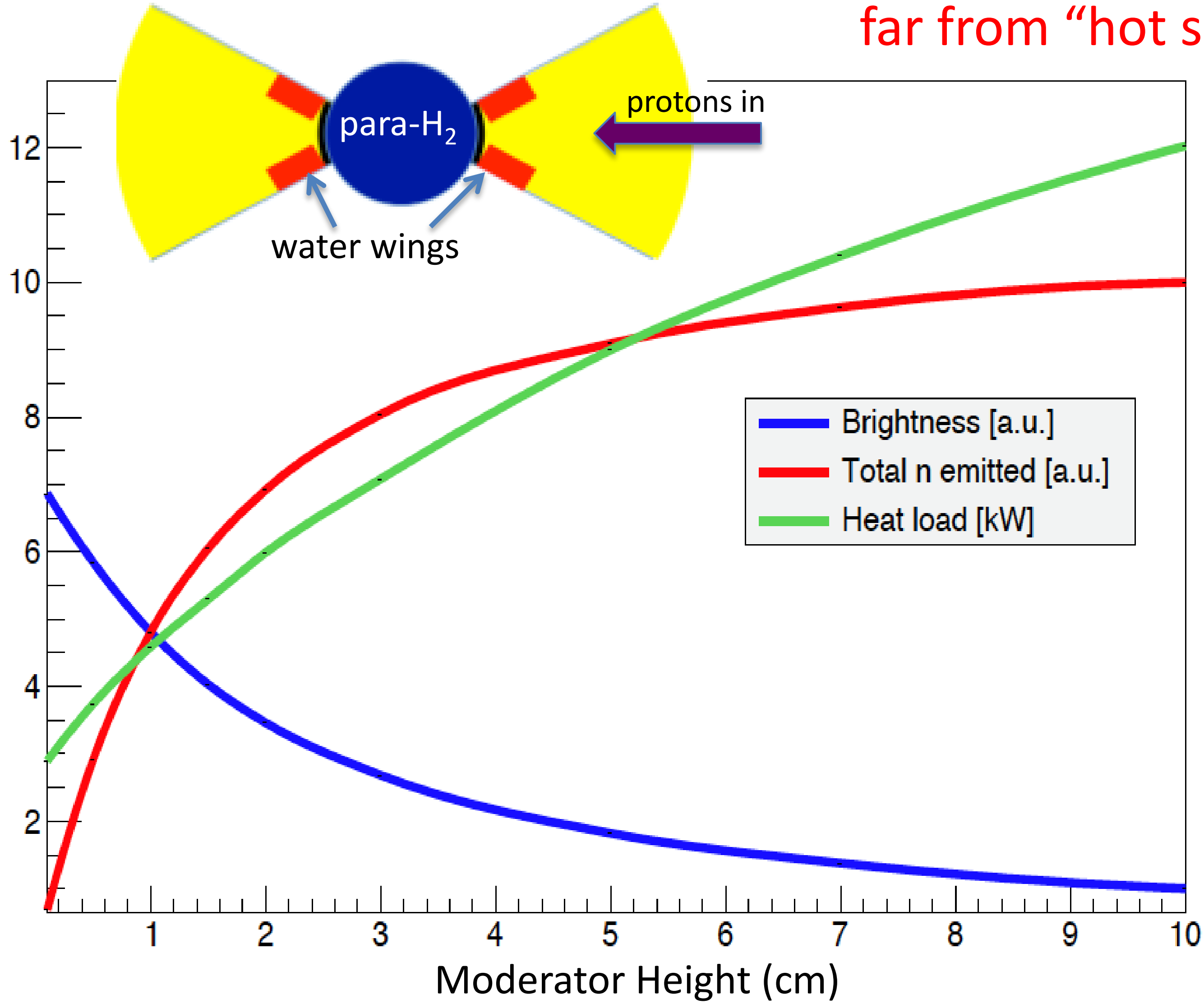


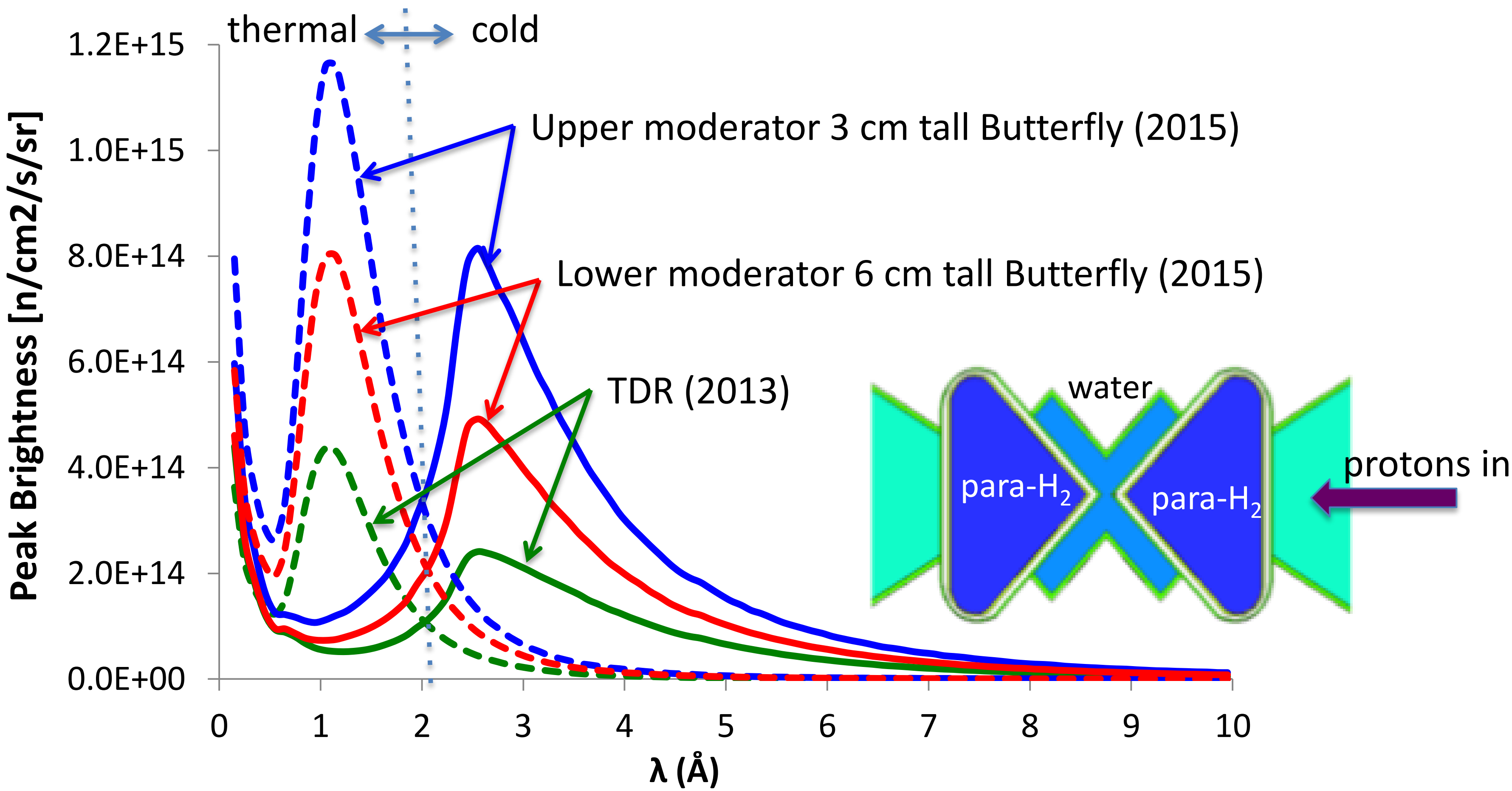

*K. Batkov, et al., NIM A 729 (2013) 500.*

# "Pancake" moderator idea showed benefit of flat moderators

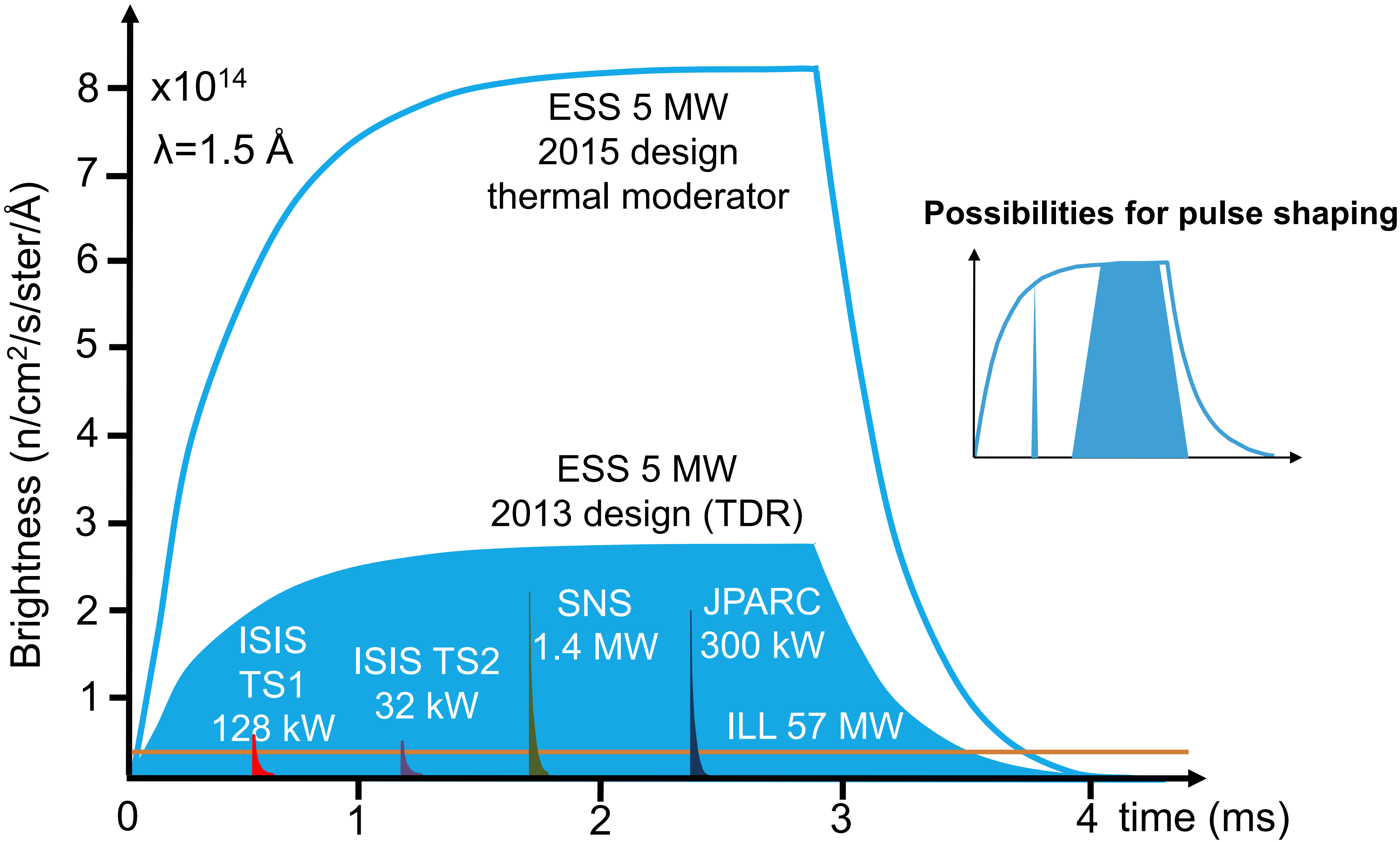
--- but thermal wings still far from "hot spot"



# "Butterfly" Moderators (New Baseline) Optimizes Cold and Thermal Neutron Brightness



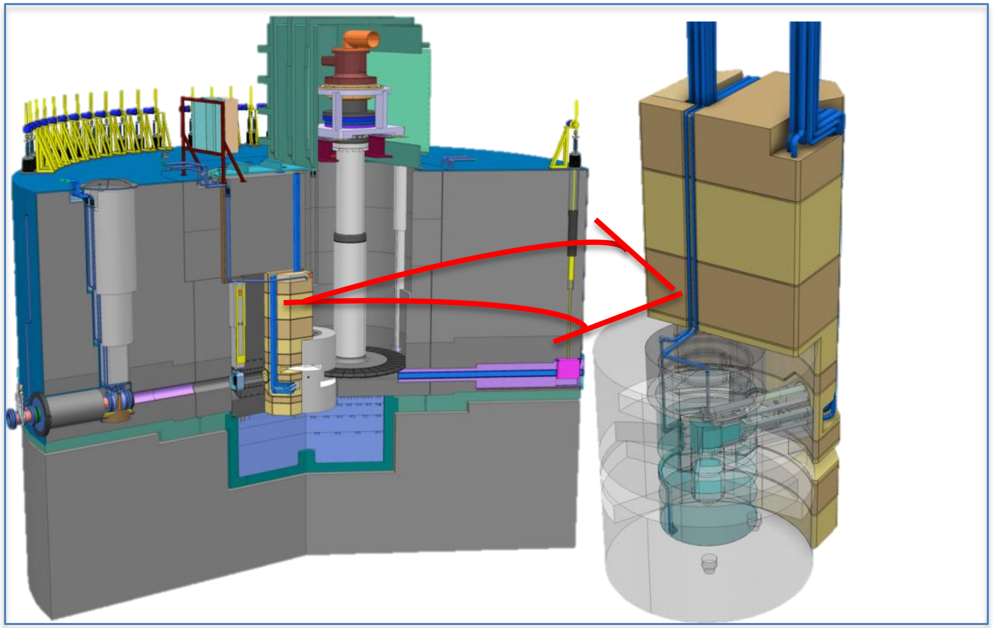
# ESS long pulse potential



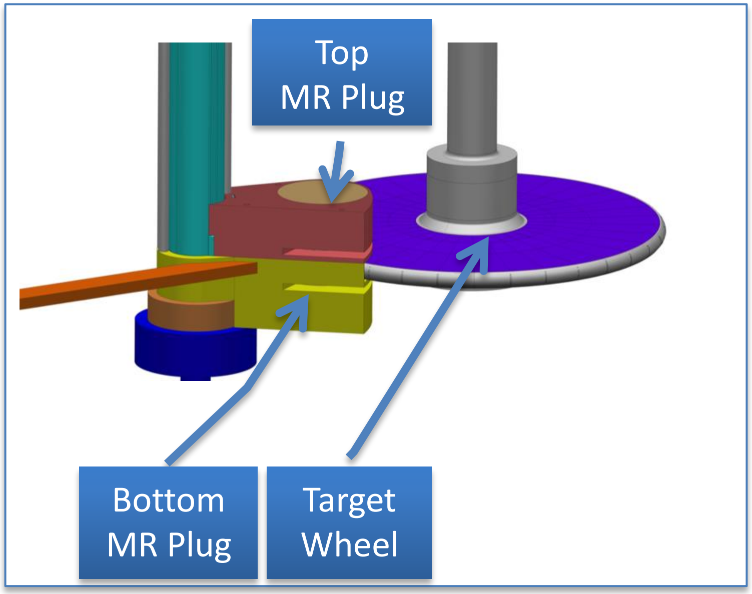
# Moderator and Reflector Engineering Also Evolved Since TDR

- Short lifetime for moderator/reflector plug means that replacement of plug needs to be as simple as possible
- Complexity of remote handling for the TDR concept was a serious concern
  - Required removal of large pieces of shielding and horizontal motion to clear the wheel before lifting
- New "twister" concept uses a rotational motion to clear the wheel, and requires significantly less removal and replacement of shielding

**TDR (2013)**

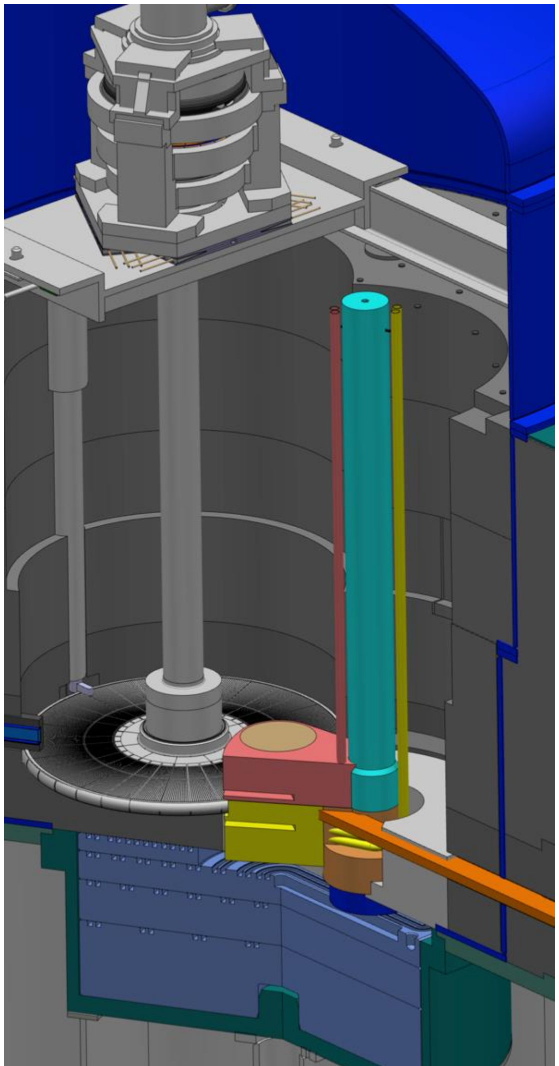


**Current Baseline (Twister)**

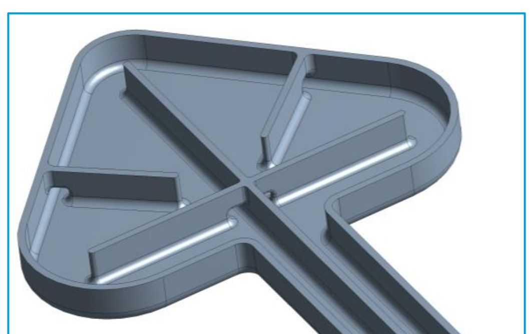


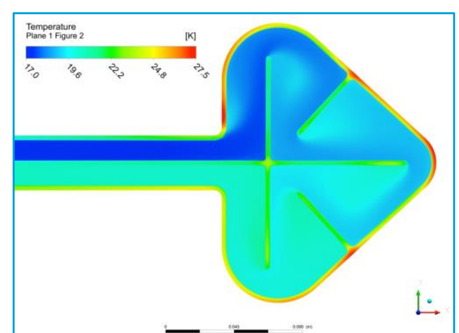
# “Twister” concept incorporates two butterfly moderators





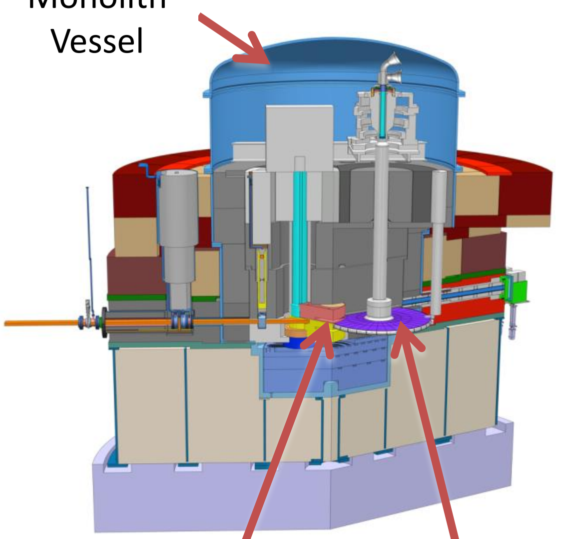
- 3 cm tall butterfly on top
- 6 cm tall butterfly on bottom
- 2 × 120° flight path openings for both moderators – all instrument positions can view either moderator
- Property changes due to transmutation (1 a% Si in Al structure) limits the lifetime to one year
- Issues being actively addressed:
  - Flat moderators require precise alignment to the neutron guides
  - $LH_2$ cooling feasibility established; optimization studies ongoing
  - Manufacturing studies underway (Al-6061 welding)

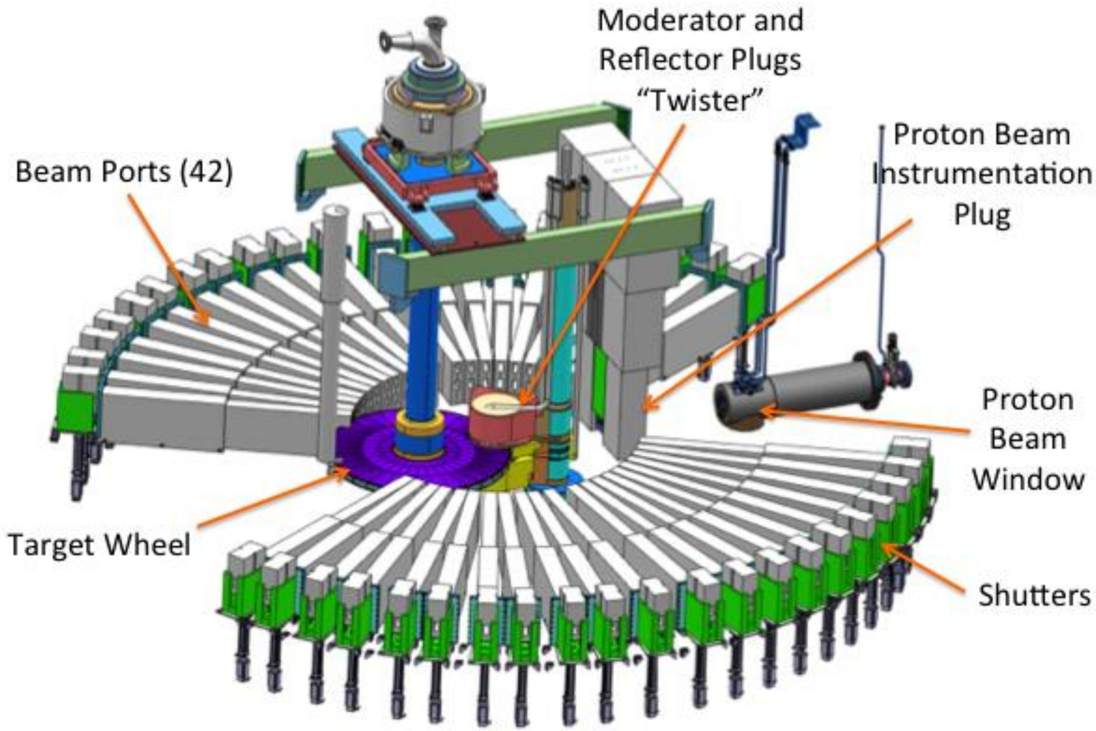




# Monolith systems
## Optimization of neutron beam extraction system

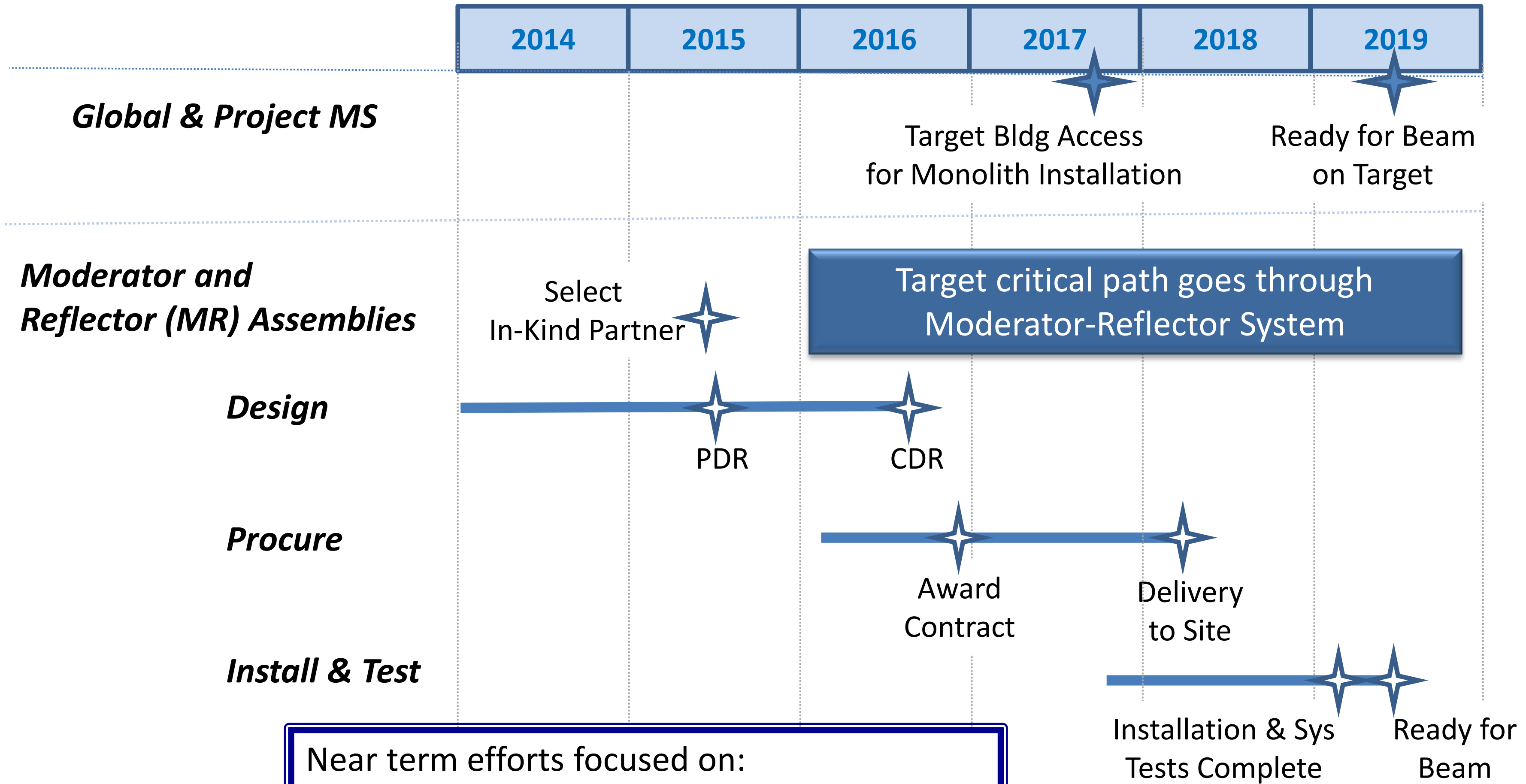
- 11 m diameter
- 6,000 tonnes of steel shielding
- He atmosphere inside vessel




- Average of 6° angular spacing between beam ports (42 ports available)
- Double decker beam inserts provide possibility to view either upper or lower moderator

# Target Project Summary Schedule




Near term efforts focused on:

- Securing in-kind partners
- Finishing preliminary design
- Providing initial hardware to integrate with Target Building construction

# Technical challenges are under control but significant risks remain

- Uncertain nuclear regulatory environment --- Sweden does not have similar facilities
  - Hired safety experts to help focus on hazards and accident analyses
  - Regularly engaging with regulator (SSM) though the ESS ES&H team

- Difficulty securing in-kind partners
  - Developed set of discreet In-Kind packages with well defined deliverables and partner selection need dates
  - Working with ESS In-Kind Management team to define and execute partner selection process

- Concerns about executing project with so much scope provided by in-kind partner
  - Incorporating clear deadlines and deliverables in agreements
  - Continuous engagement with partners for early identification and resolution of issues
  - Establishing Target Collaboration Board to push on results

# ESS Target Project – Concluding Remarks

- Target Project scope, requirements, budget, and schedule well understood
- Key design decisions finalized and being implemented
  - Large neutron source performance and flexibility gains secured
  - Improved designs for wheel, moderator/reflector plug, beam extraction, shielding, He purification, and active cells
- Aggressive schedule meets 2019 Beam-on-Target commitment with 6 months float
  - Focusing on completion of Preliminary Design phase, interface with Target Building, and In-Kind Partnering
- Addressing key risks associated with In-Kind partnering and regulatory framework for radiation safety