EUROPEAN SPALLATION SOURCE

ESS Accelerator: Overview, and Considerations for Neutron Instruments

29 August 2013

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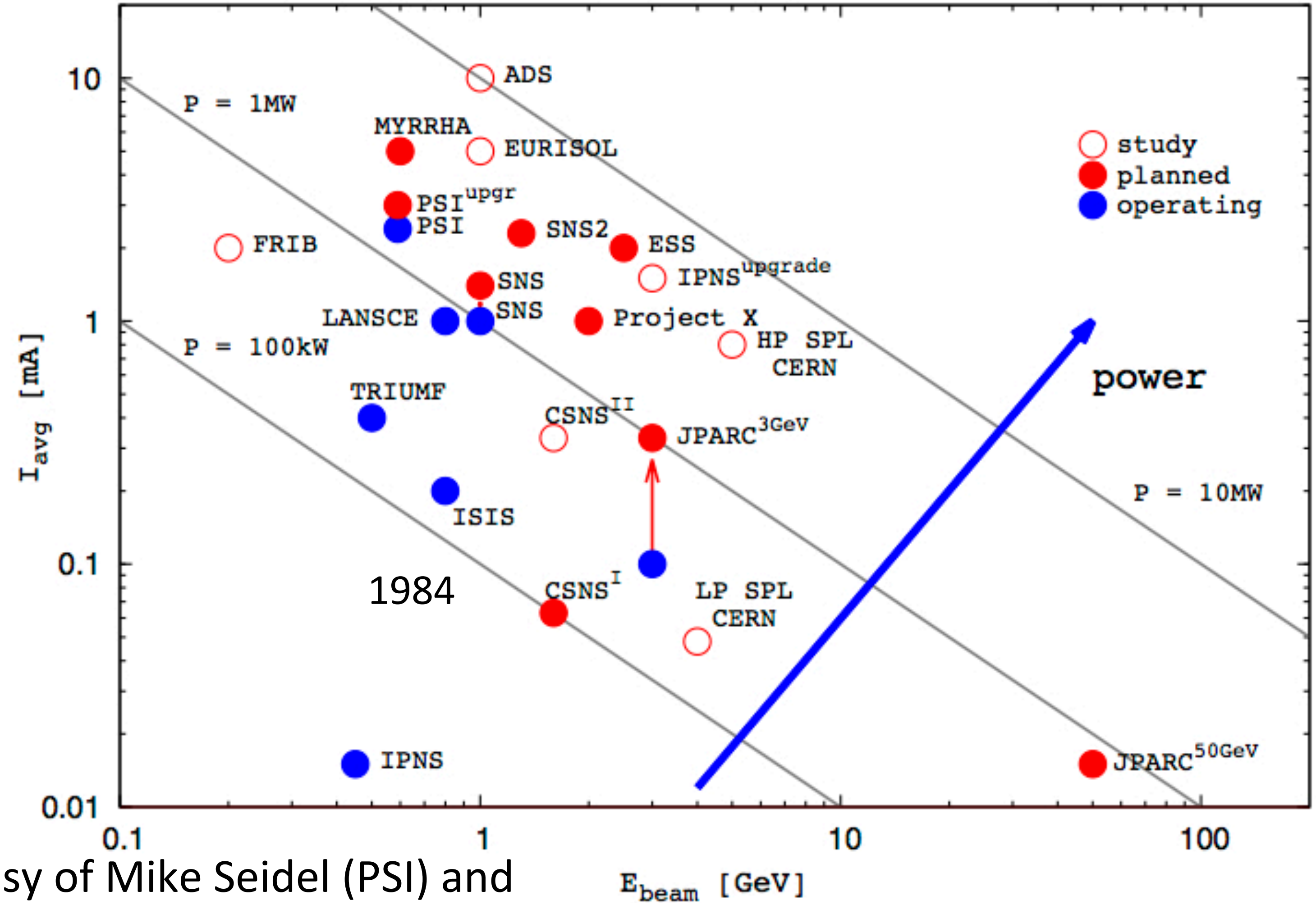
The hadron intensity frontier



Courtesy of Mike Seidel (PSI) and Emmanuel Laface (ESS)

ESS accelerator

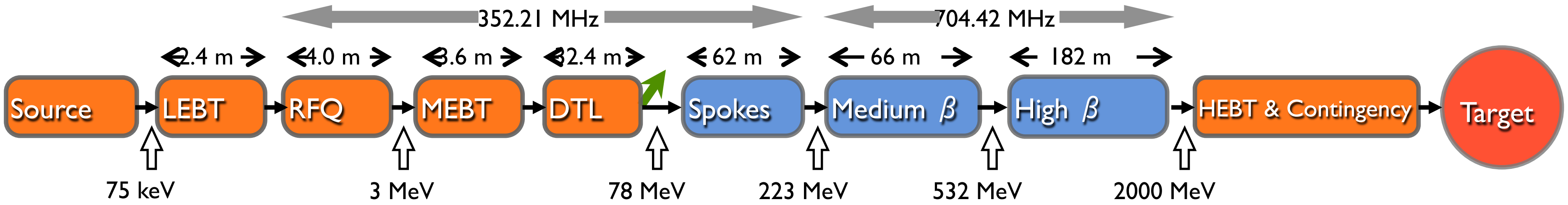
Design Drivers:

- High Average Beam Power
  - 5 MW
- High Peak Beam Power
  - 125 MW
- High Availability
  - > 95%

Key parameters:

-2.86 ms pulses
-2 GeV
-62.5 mA
-14 Hz
-Protons (H+)
-Low losses
-Low heat loss cryostats for minimum energy consumption
-Flexible design for future upgrades

ESS Linac



	Energy (MeV)	No. of Modules	No. of Cavities	β g	Temp (K)	Cryo Length (m)
Source	0.075	1	0	–	~300	–
LEBT	0.075	–	0	–	~300	–
RFQ	3.6	1	1	–	~300	–
MEBT	3.6	–	3	–	~300	–
DTL	79	5	5	–	~300	–
Spoke	220	15	2 (2S) × 15	0.5 β_{opt}	~2	4.14
Low β	520	8	4 (6C) × 8	0.67	~2	8.28
High β	2000	22	4 (5C) × 22	0.86	~2	8.28
HEBT	2000	–	0	–	~300	–

Elliptical Cryomodule Components

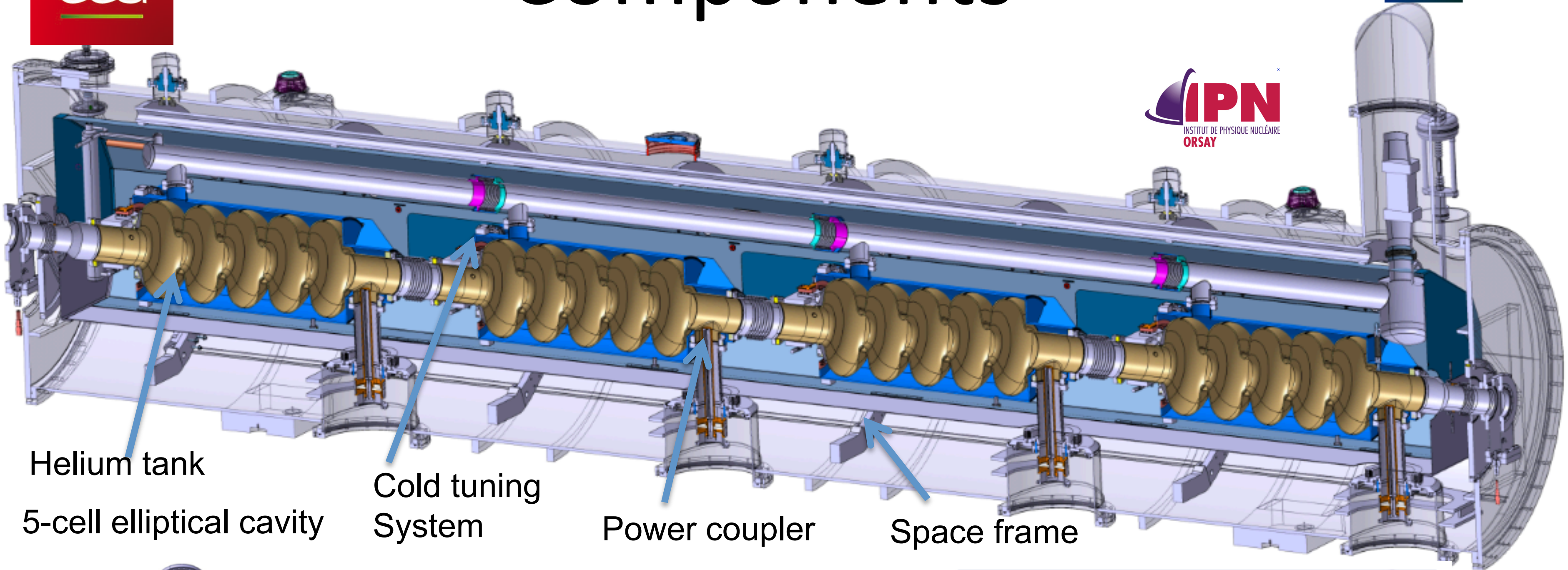
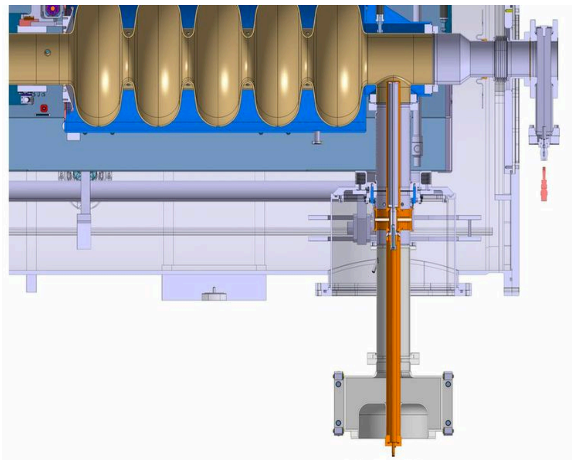
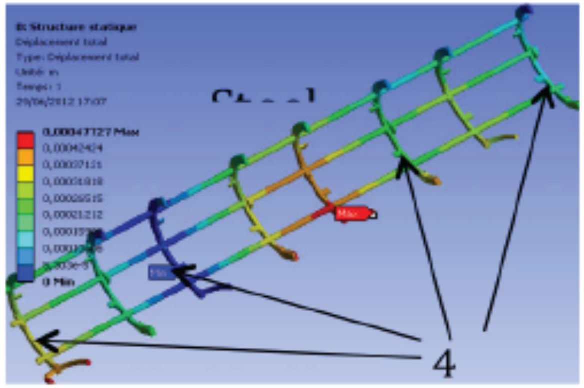
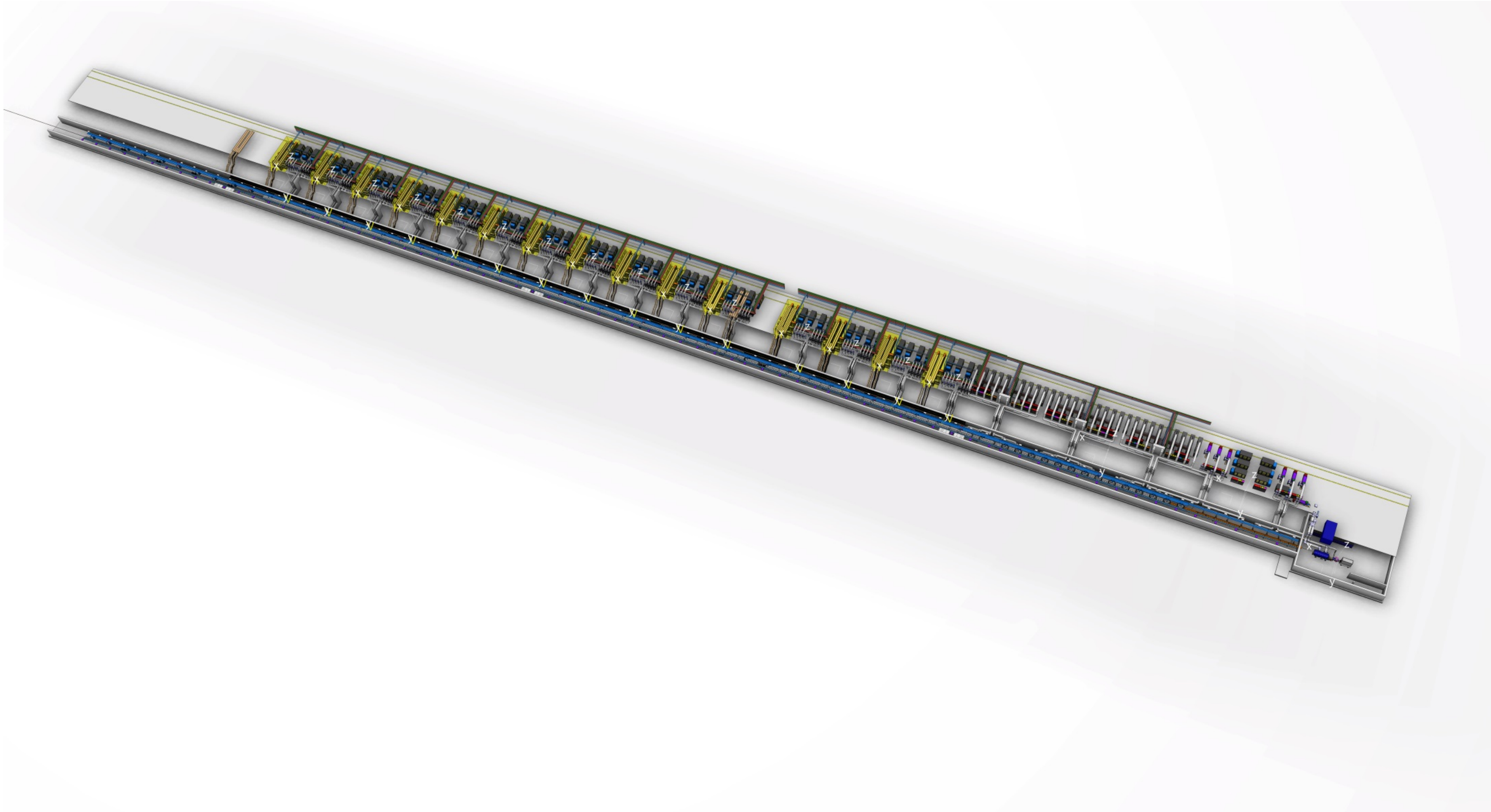


Figure 4.120: Helium vessel with hanging rod





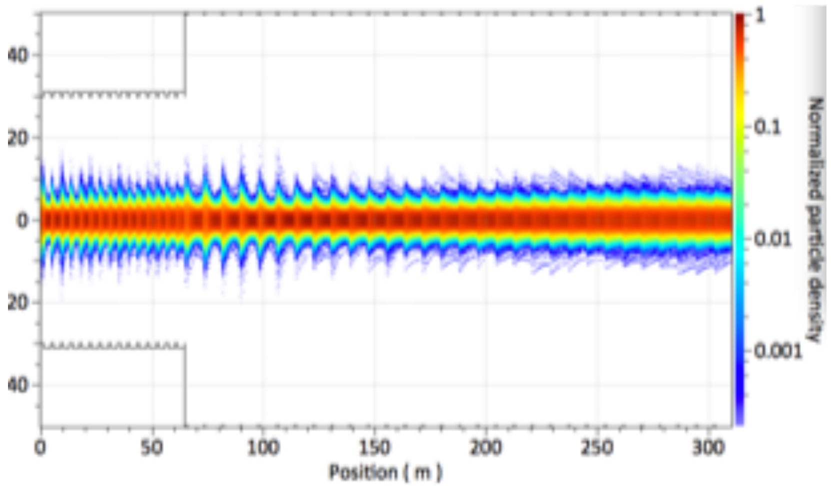


Notes on Accelerator Design

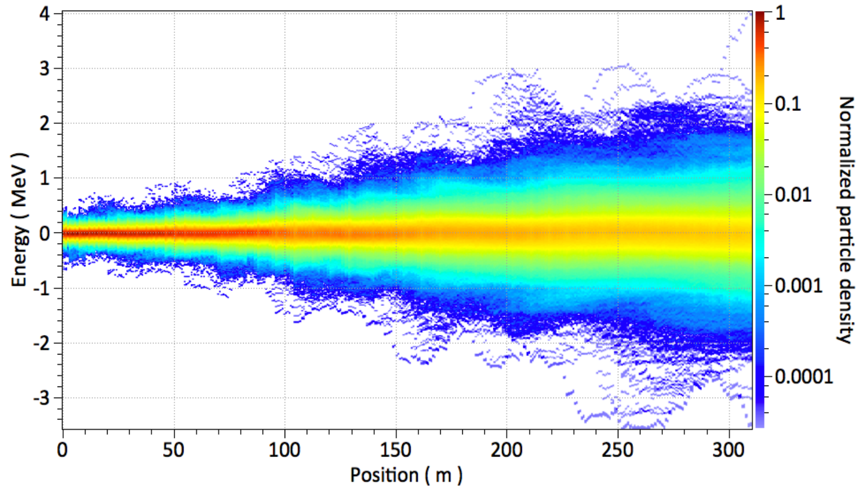
- ESS is unique: **Long pulse source**
  - Couples neutron instruments to accelerator – we have done this before (more like a collider than we had realized)
  - High quality beam (bright core) all the way to target: small changes in beam transport can produce significant damage. Actively expanded in old TDR design (quads & octupoles), and the new design (quads & fast dipoles)
- Accelerator Design Update 2013
  - Reduce cost: aggressive design
  - Caused us to think about beam quality and rethink transport to target
- Small paintbrush (precision) vs. large (splat)
  - Must be precise with 5 MW. Desire uniform core, well-controlled edges.
  - Sensitive to the smallest details (activation, neutron background). Can't predict details of beam distribution, so why magnify details?

Proton Beam Simulations

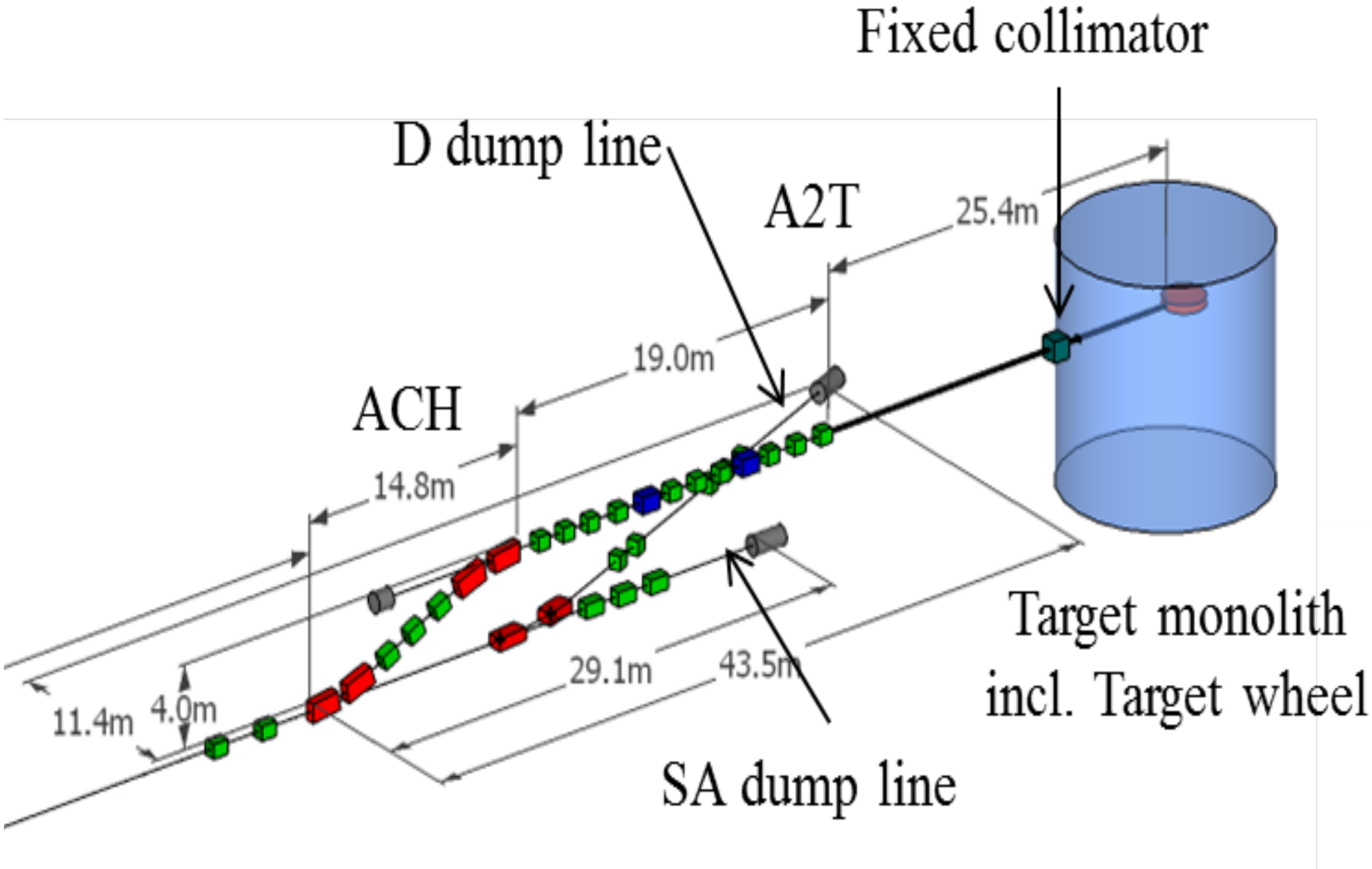
Transverse extent along linac



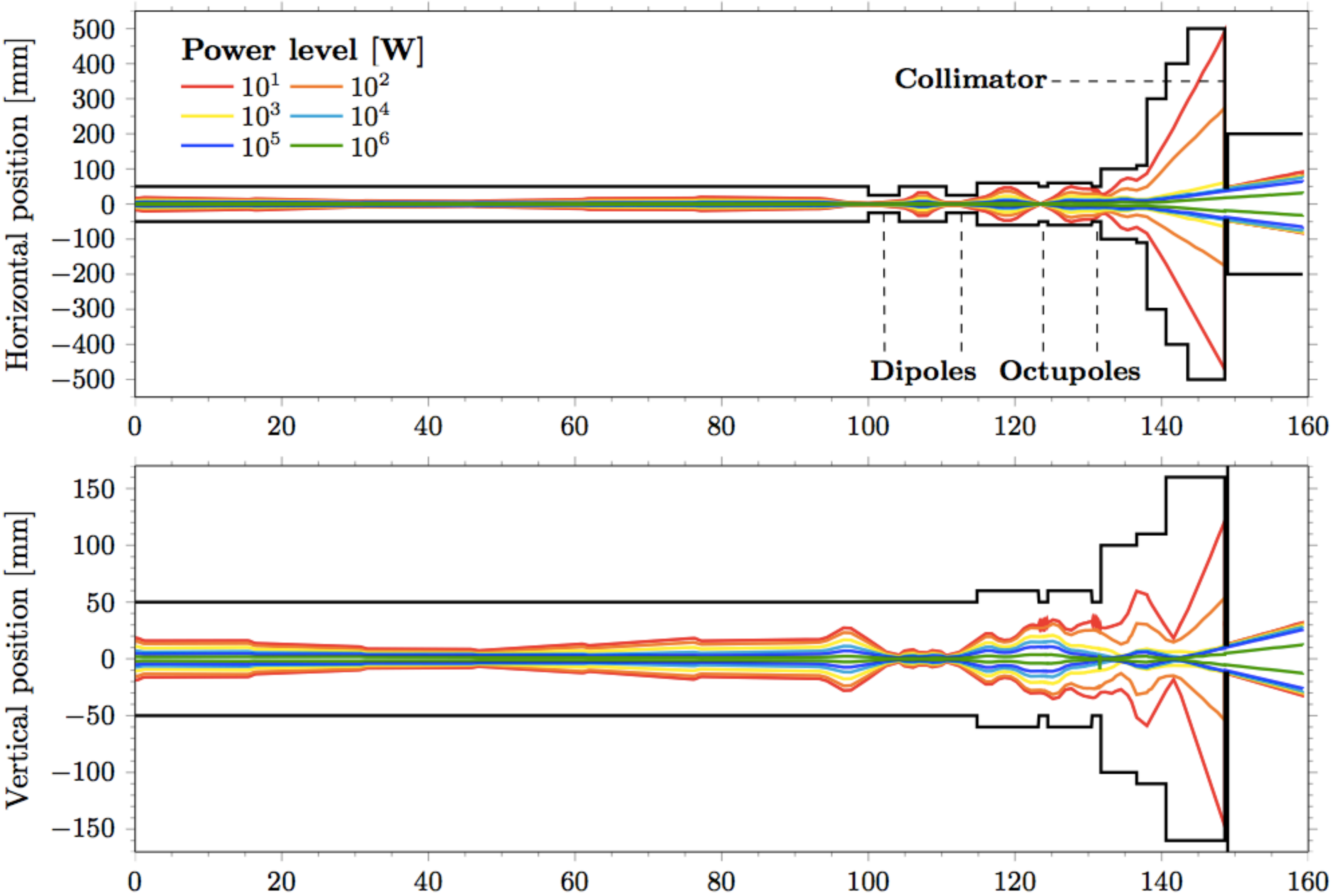
Energy variation along linac



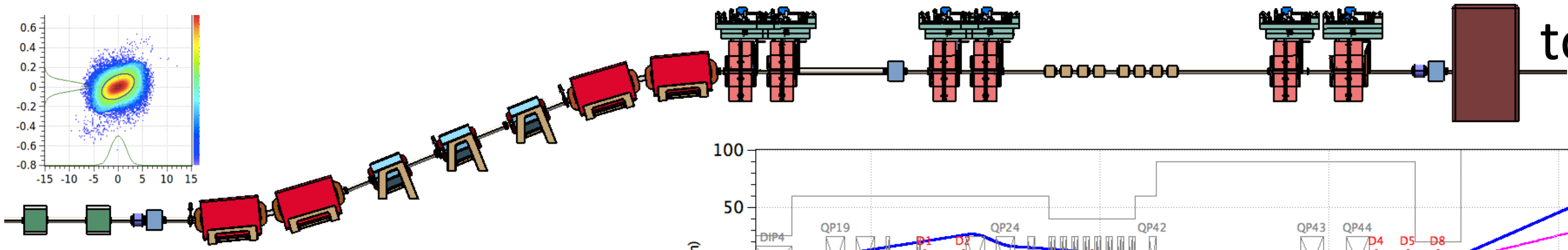
A2T Layout in TDR

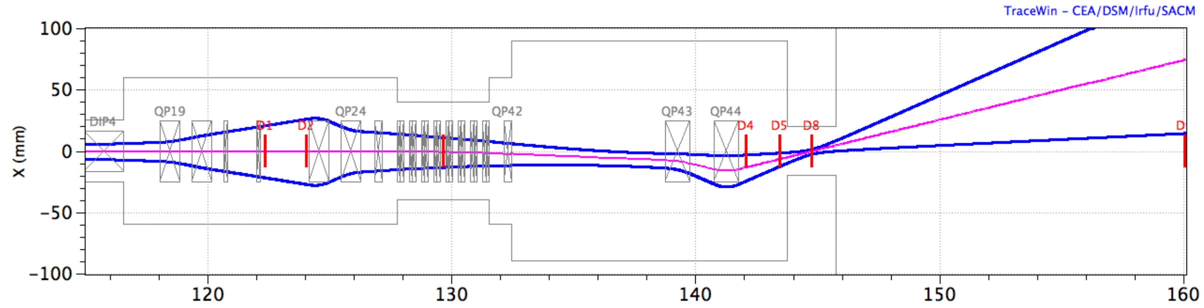


A2T Proton Optics in TDR



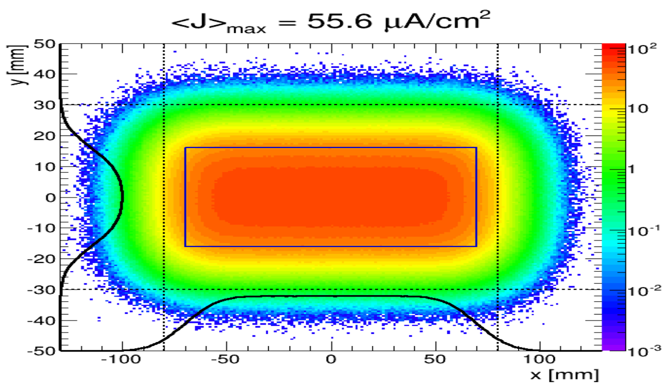
A2T Design Update





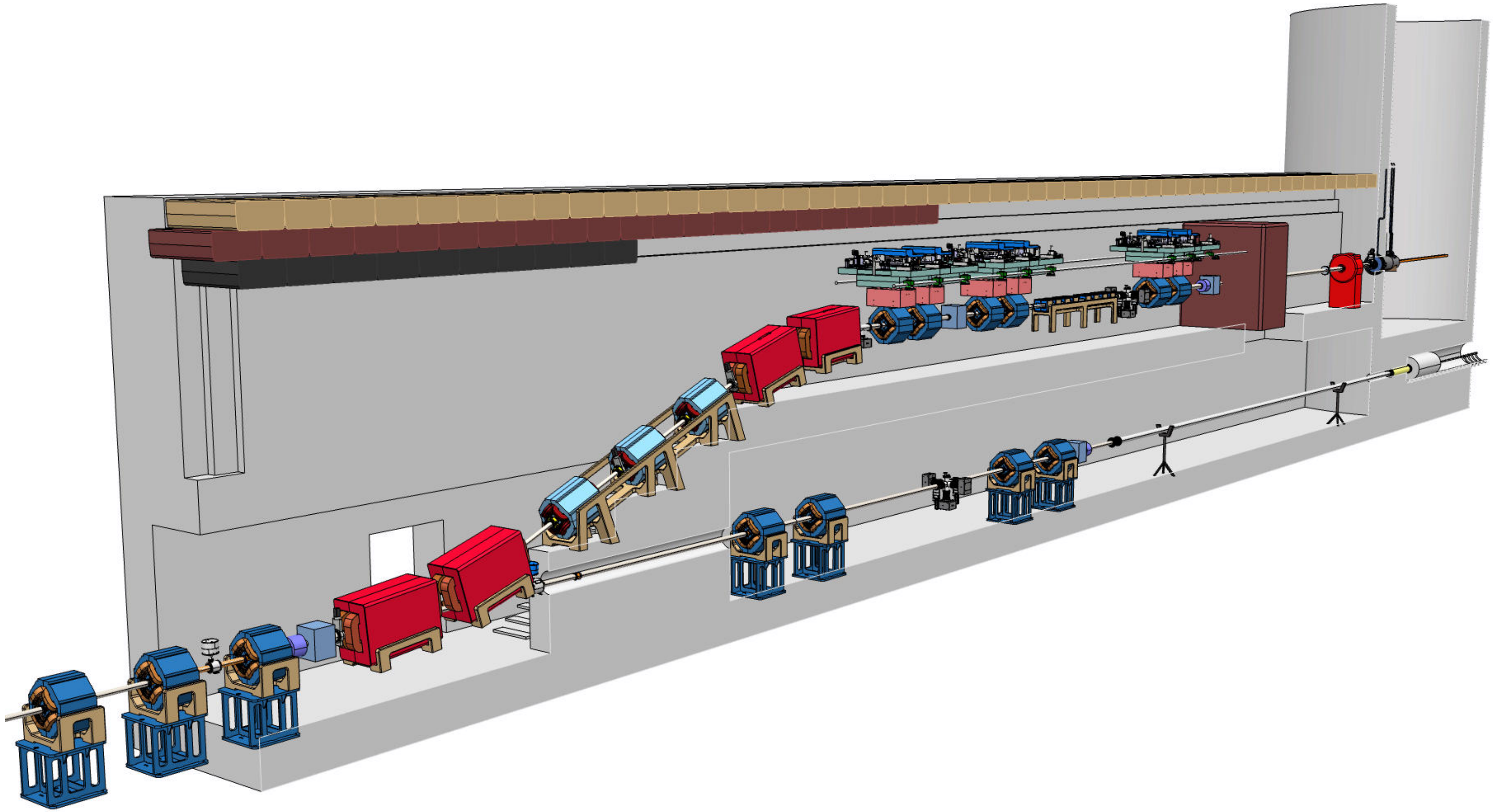
Beam on Target

- 2 GeV protons (was 2.5 GeV)
- 62.5 mA (was 50 mA)
- Pulsed: 5 MW average, 125 MW peak
- Expanded: from ~2 mm RMS to 160 by 60 mm footprint on target
- Beam rastering is now baselined



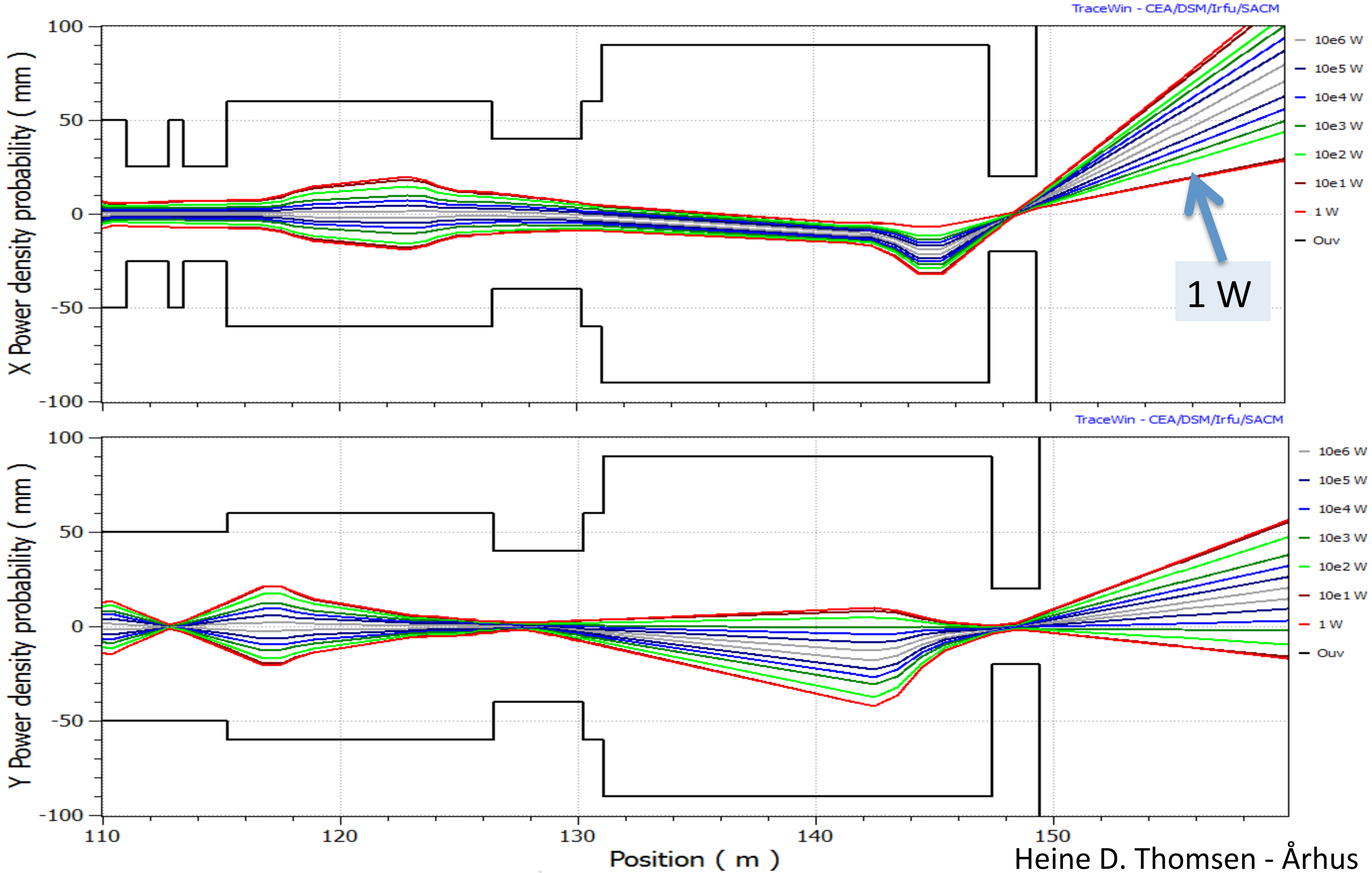
55 µA/cm^2 nominal density on target

A2T Enclosure Development



5M Particles from Latest SCL

- Initial raster design, but similar to current reference design - No lost particles

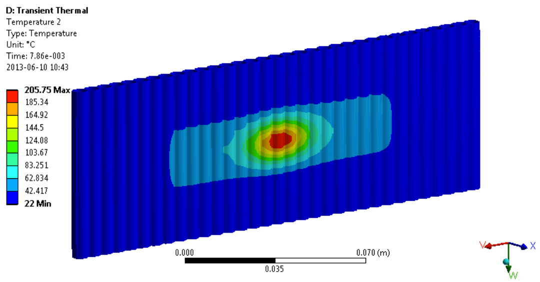


Heine D. Thomsen - Århus

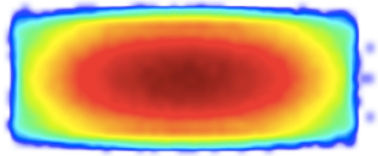
Target

- Analysis of reference raster design:
  - Current aluminum window design OK for nominal beam. Survives full unrastered pulse, but replacement recommended.
  - Initial analysis of Titanium window: OK for nominal beam. Survives one full unrastered pulse with no need for replacement.
- Rastering helps and introduces no significant issues

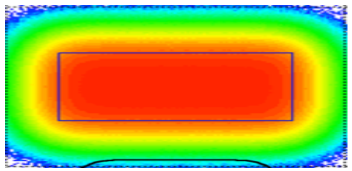
Window analysis



For 62.5 mA beam at proton beam window:



Octupole 2012: 105 µA/cm^2



Raster 2013: 88 µA/cm^2

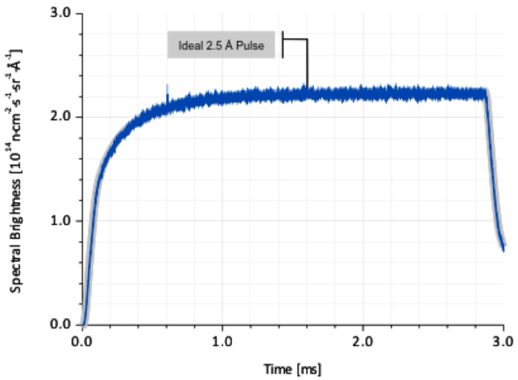
→ **Target: rastering is preferred; reduced heating**

Target Analysis: Pitcher, Sabbagh, Takibayev (also neutronics), et. al.

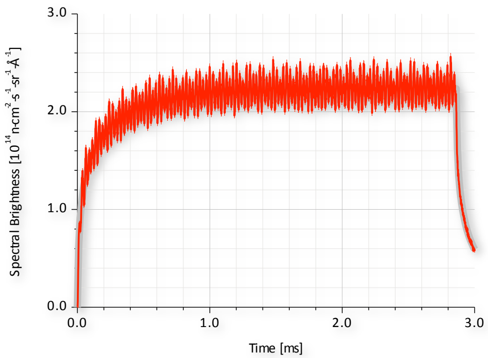
Neutron Instruments

- Only the shortest wavelengths of thermal spectrum are noticeably affected
  - No showstoppers identified
  - Brainstorming about potential opportunities

Cold: very little modulation (less than **proton intensity fluctuations**)



Thermal: more modulation (correct, average away, or ignore)



Neutron Instruments: Rastering is supported; Reduced background, possible opportunities.

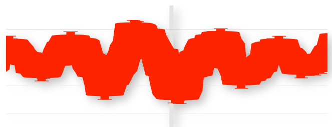
Assessment: Henry, Bentley, Anderson, ESS instrument scientists, et al.

Alternate neutron pulse shapes

Fast raster

"A" Pulse:
modulation

"B" Pulse:
inverted modulation

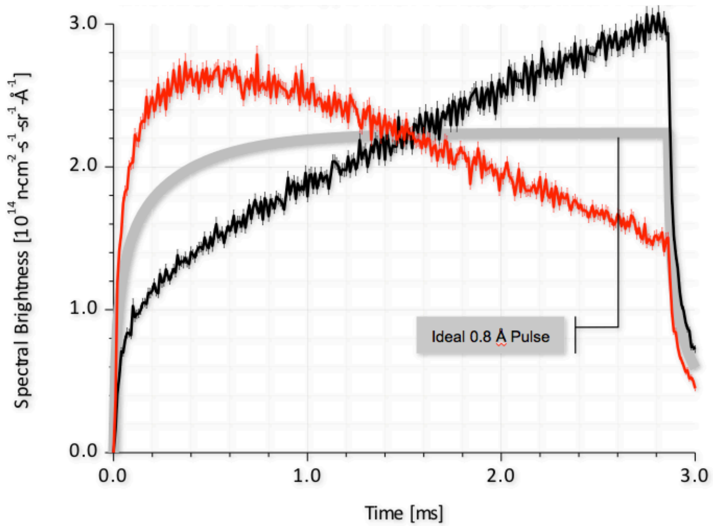


Result:
Bin A and B together

Or bin A and B separately to retain shape

Slow raster

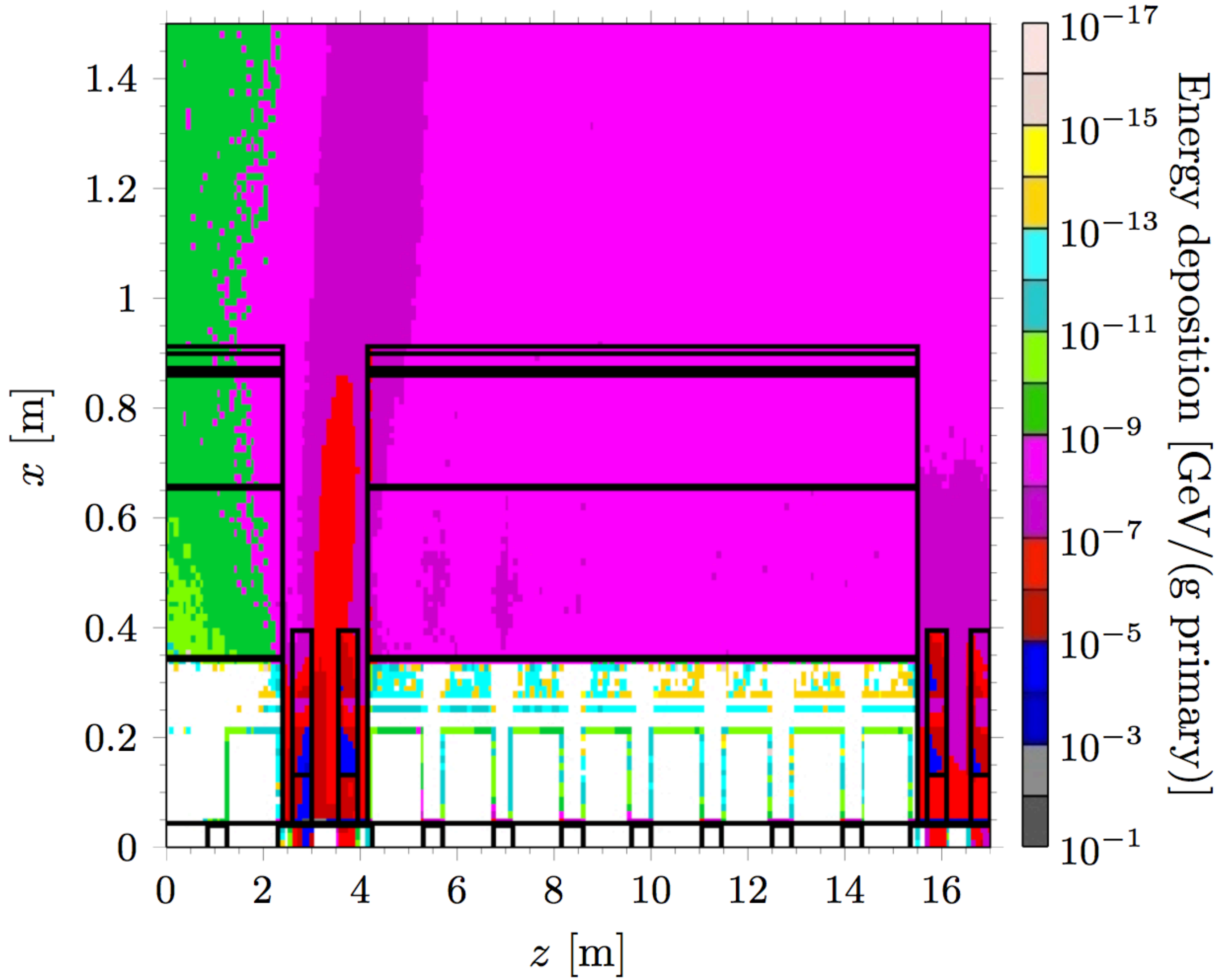
Thermal with slow horizontal raster: pulse shaping



Monte Carlo Simulations for ESS Linac

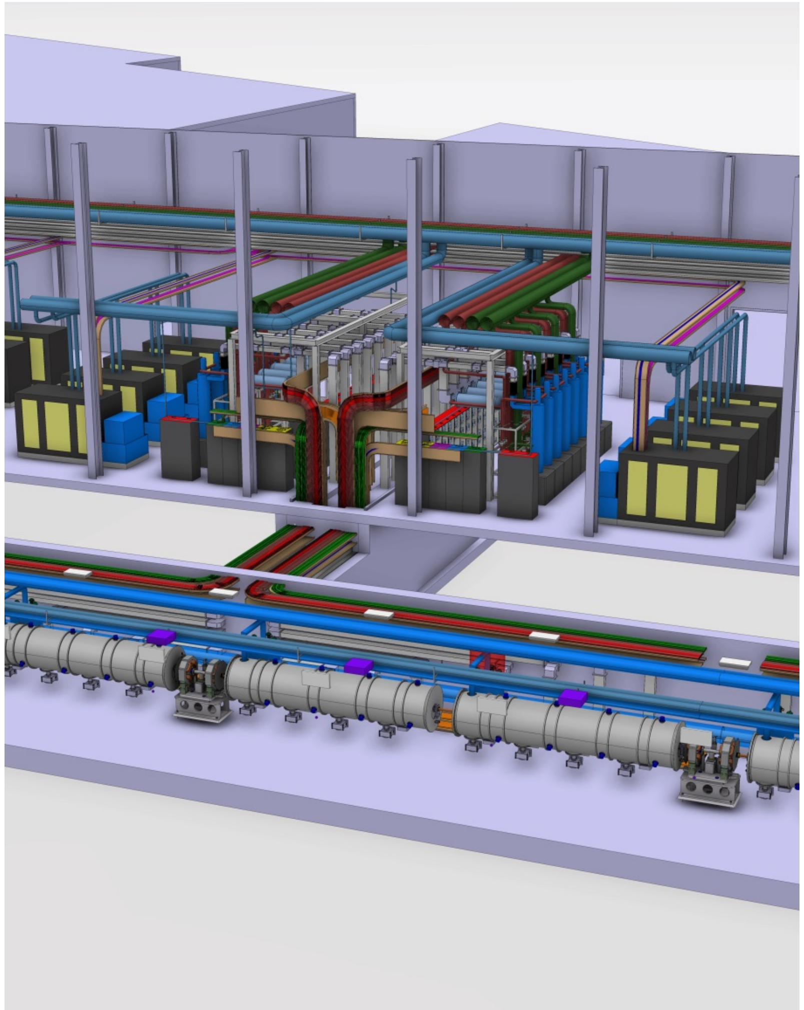
- We use MARS monte-carlo code (similar to GEANT, FLUKA, MCNP) for accelerator related calculations.
- Current layout of entire ESS linac is modeled including a simplified target at the end.
- Early results have already driven some design changes

Supporting Beam Loss Monitor Design

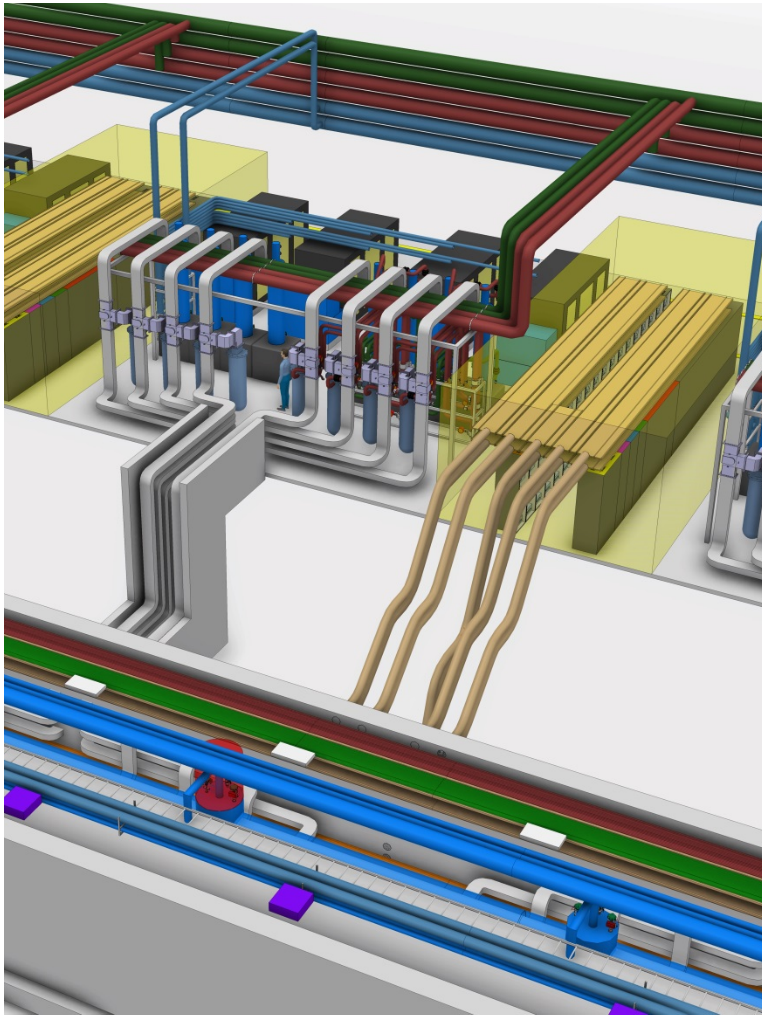


Revised Stub Design

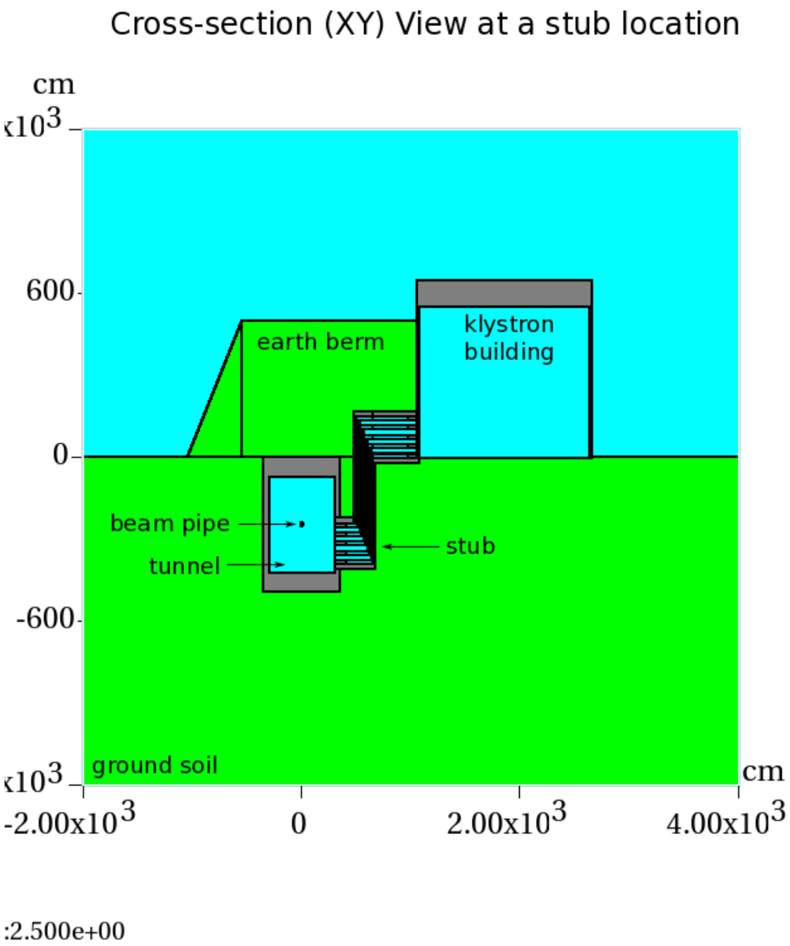
Old

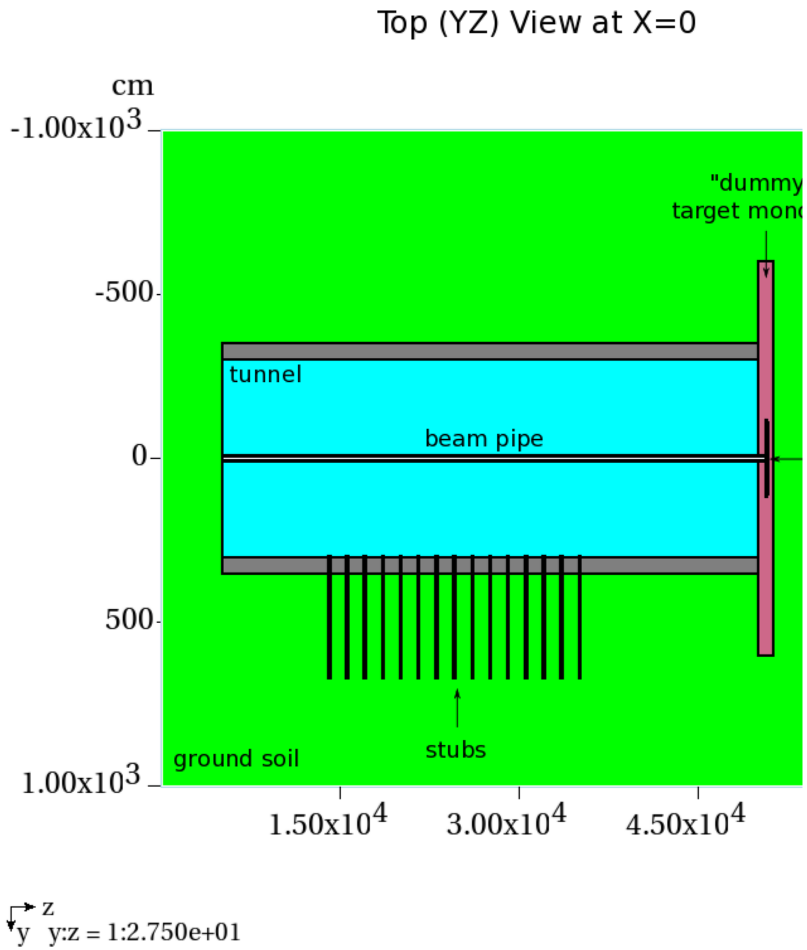


New



Geometry Model of the Linac

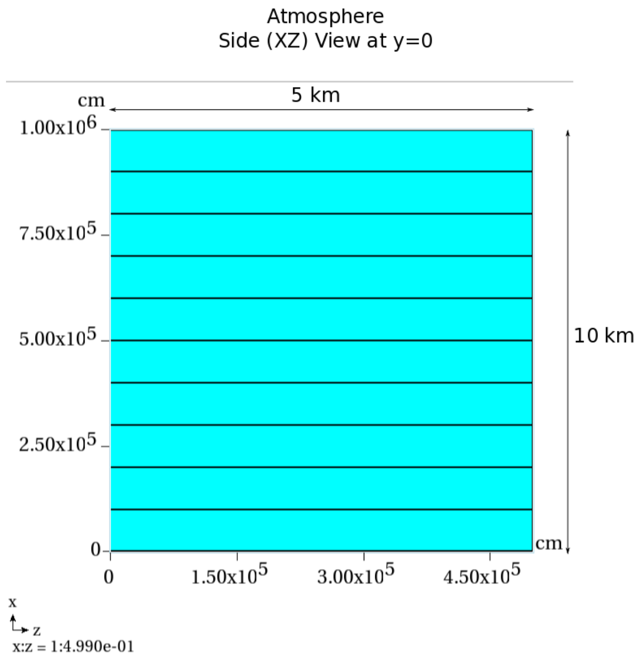




11 HB and 4 MB stubs are included in the model.

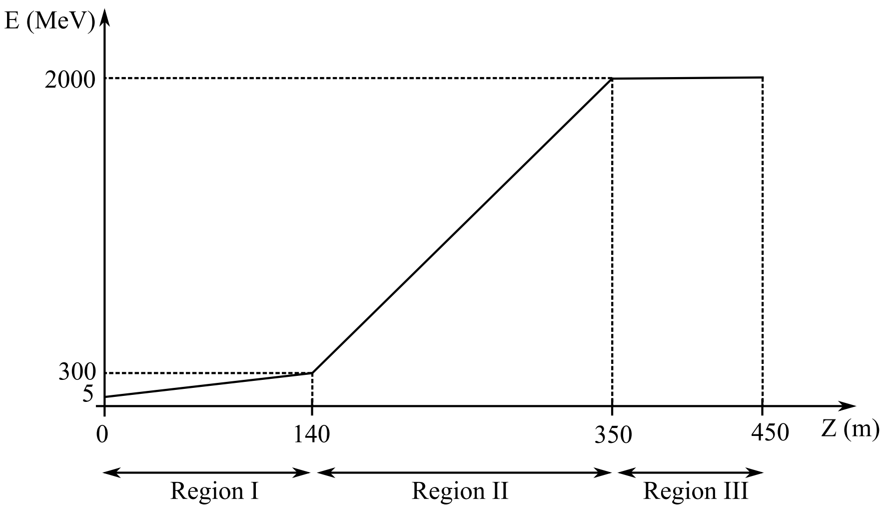
Monte Carlo Simulations for skyshine calculations

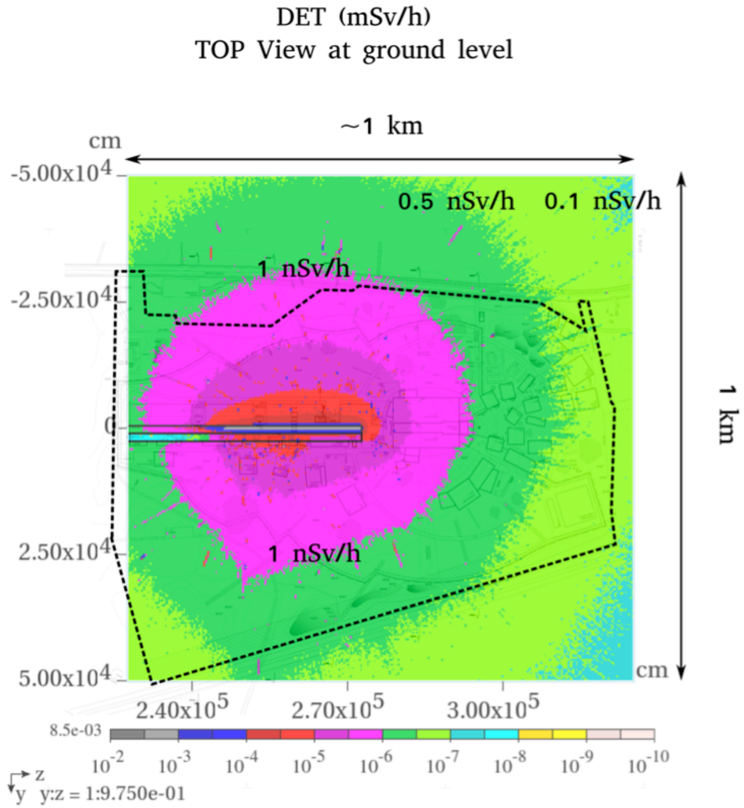
- Ten 1 km layer of atmosphere is included in the model.
- Various energy neutrons escaping the linac shielding are saved in a source term for skyshine calculations.
- Skyshine is calculated across the ESS site. List of some of the parameters calculated are given below.
  - **DET** (dose equivalent total),
  - **FLN** (total neutron flux),
  - **FLN>E** (neutron flux above energy E).



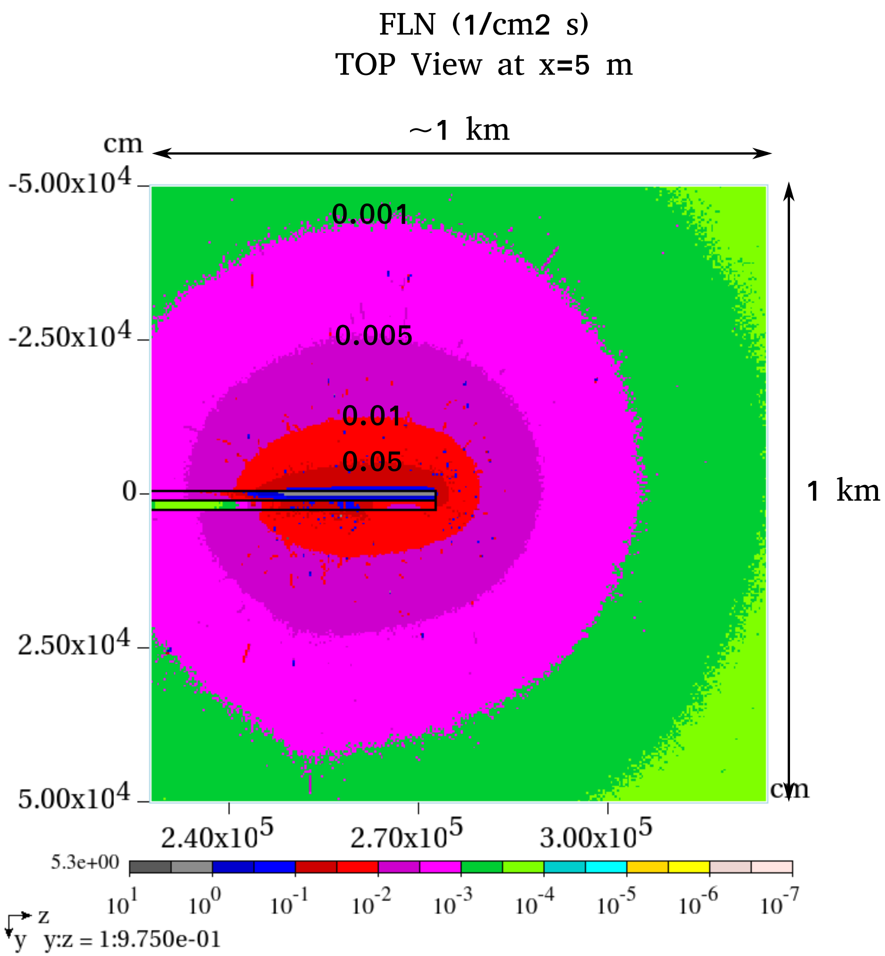
An example of dose rate map across the ESS site

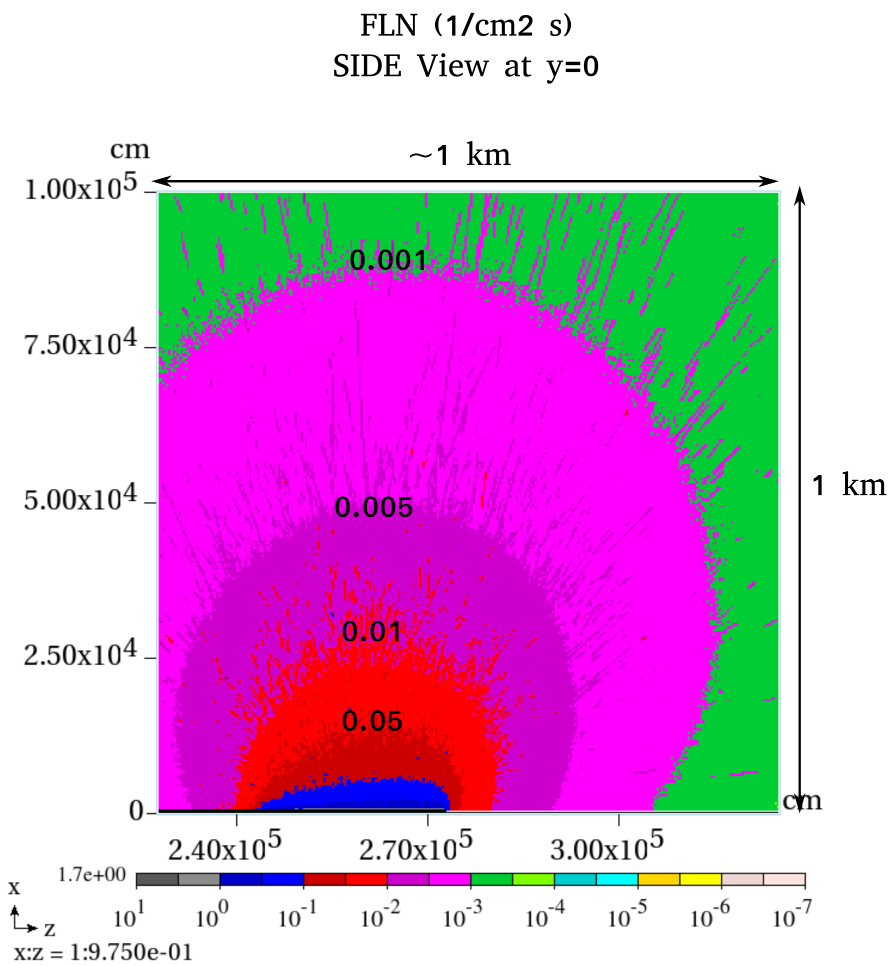
- Contribution from the straight section of the linac is calculated so far.
- Normal operations 1 W/m losses are assumed (goal: 0.1 W/m).





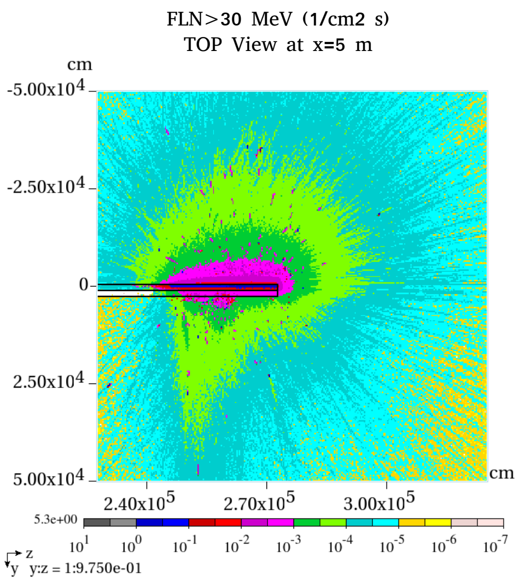
Neutron flux (total) across the ESS site

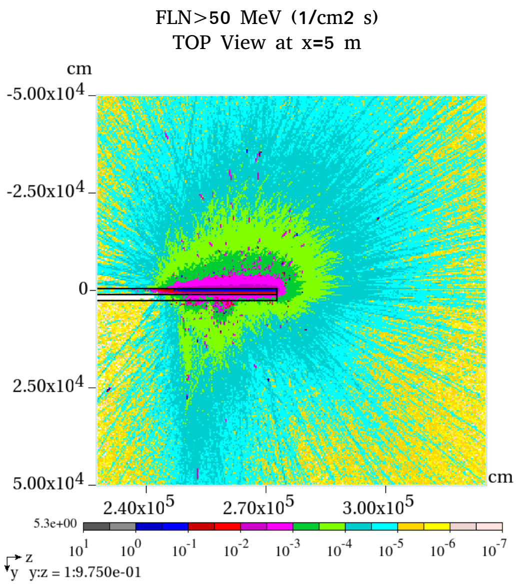


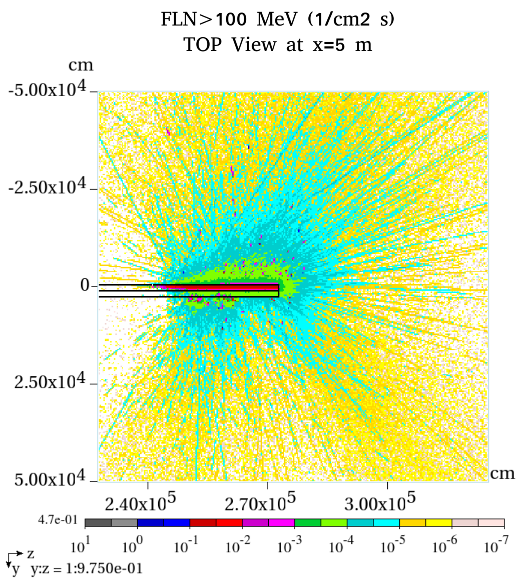


Neutron fluxes above certain thresholds

WITH STUBS



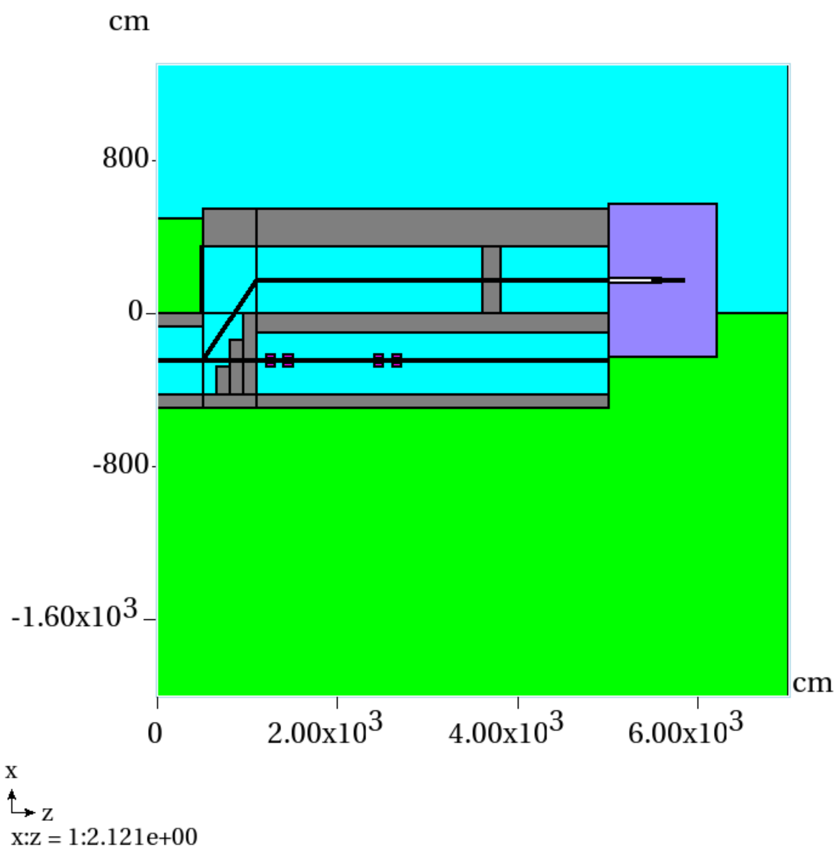




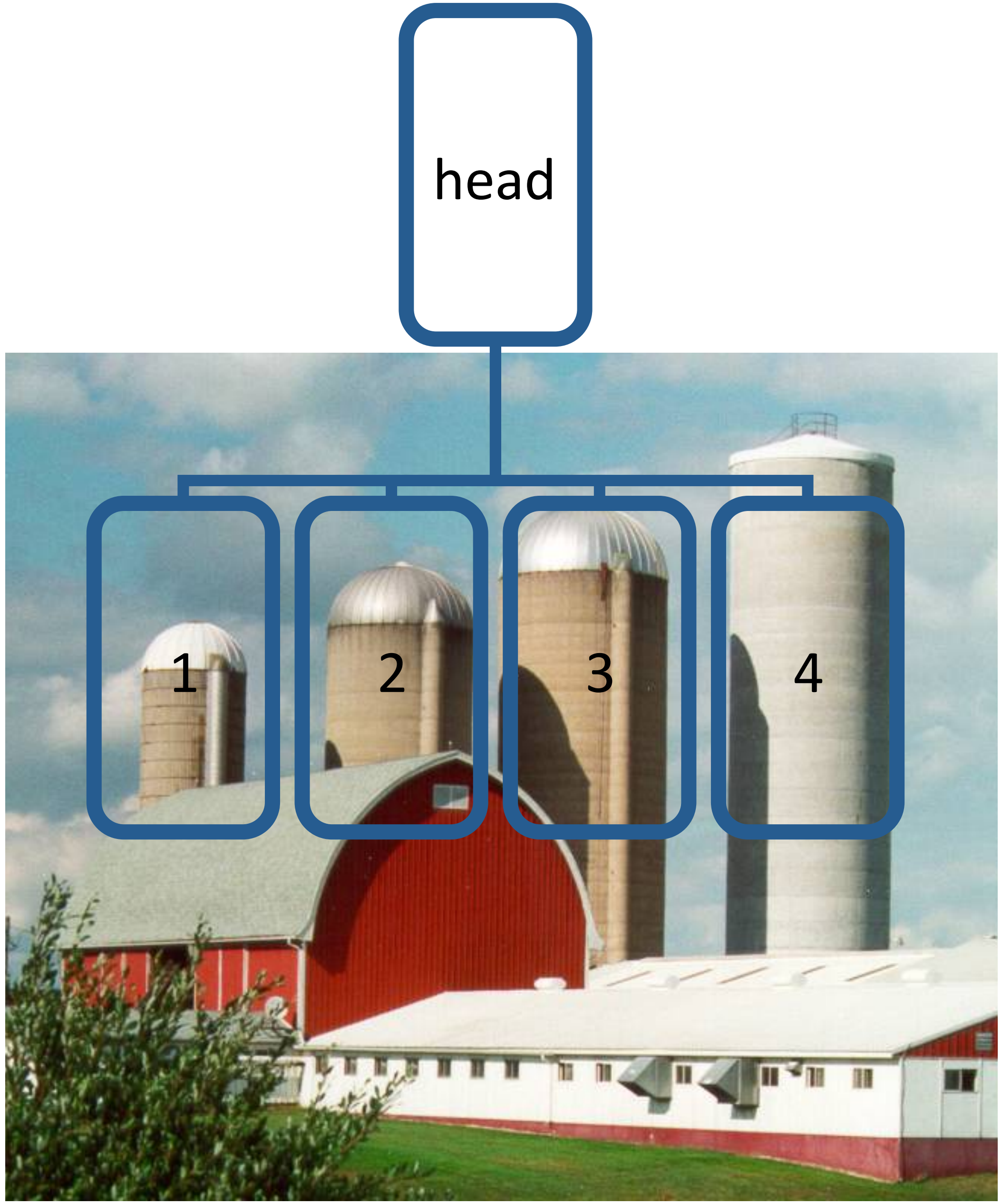
Next steps

- Include A2T area in skyshine calculations.
- Model neutron bunkers at various locations across the site.
- Calculate neutron fluxes above threshold energies inside the neutron bunkers.

A2T side view



communication performance
is correlated with
technical performance*



*Allen, Goldhar, Baker, 1964 and on

Closing thoughts

- Accelerator design - end to end simulations
  - Tradition: from source to target
  - Goal: from source to sample
- Good start on communications between accelerator, target and neutron instruments
  - Will be challenging to keep it up as project pressure builds
  - But important for long pulse source. Also fun.
- Other opportunities
  - Resource sharing during construction
  - Accelerator experts help with instruments