EUROPEAN SPALLATION SOURCE

Beam Commissioning of the ESS Accelerator - Results and Challenges

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On Behalf of the Beam Physics Group

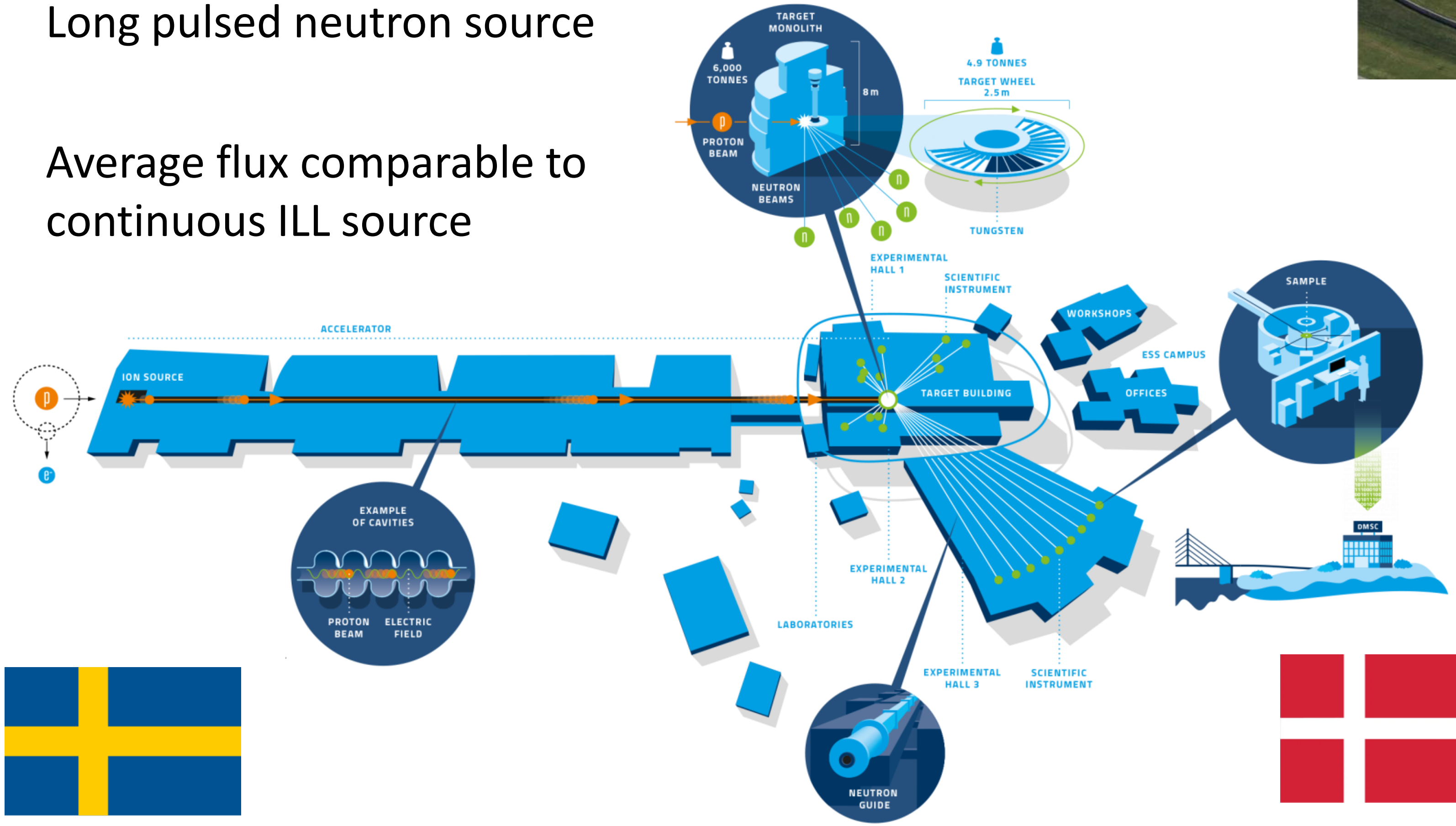
DAEJEON LINAC 2026

The European Spallation Source

European collaboration, 13 member states

Long pulsed neutron source

Average flux comparable to continuous ILL source



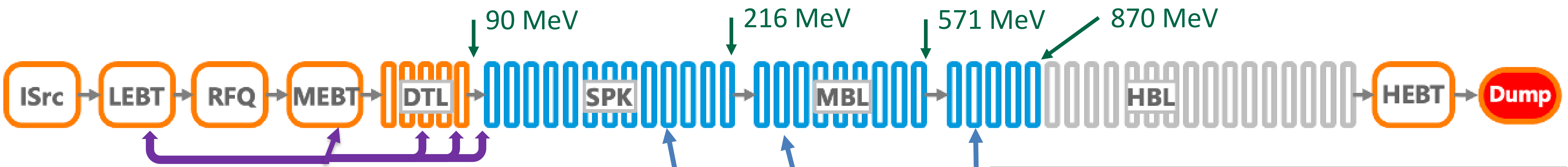
Neutrons are produced by spallation

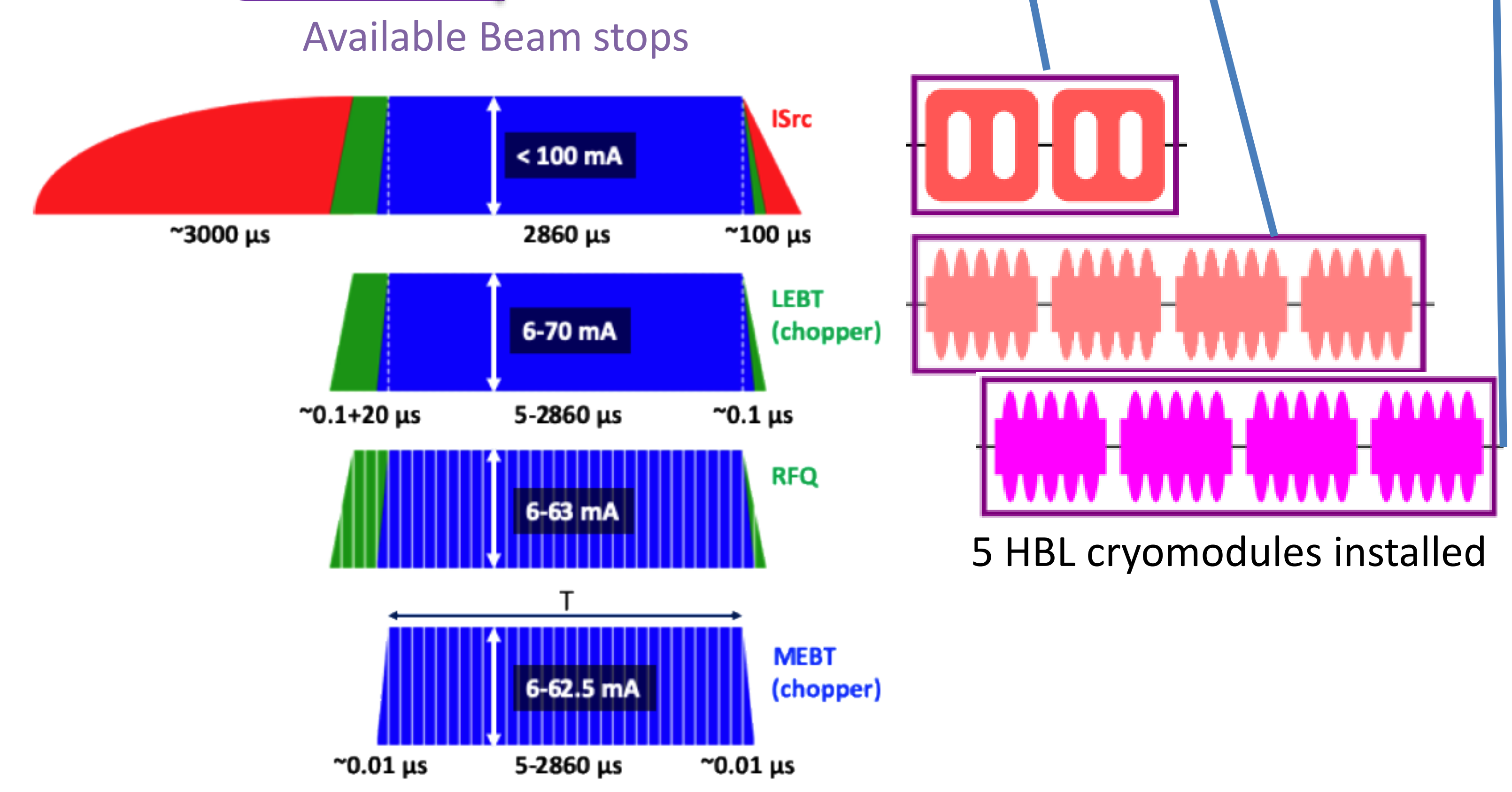
Rotating tungsten target

15 planned instruments

- 5 expected to be ready for neutrons in 2027

The ESS Proton LINAC





Parameter	Nominal	BOD 2025
Beam Power	5 MW (2 MW)	$2\cdot 10^{-5}$ MW
Beam Energy	2 GeV (0.88 GeV)	0.8 GeV
Peak Beam current	62.5 mA	6 mA
Beam pulse length	2860 us	5 us
Rep. rate	14 Hz	1 Hz
RF freq	351.21MHz/704MHz	

Timeline of the ESS project

Approval date

May 2009

RESEARCH FACILITIES

European Neutron Source Finally Finds a Home

After a frustrating decade watching their preeminence in neutron-beam science ebb away to newer facilities in the United States and Japan, European researchers got some good news last week: Their €1.4 billion dream machine, the European Spallation Source (ESS), which has been on the drawing board for more than 15 years, overcame a major hurdle when the countries interested in funding the project picked a site on which to build it in Lund, Sweden. "This is the real thing, something we can focus on and move forward," says Robert Cywinski of the University of Huddersfield in the United Kingdom, spokesperson for the ESS preparatory phase project.

Government ministers are not getting out their checkbooks yet, as there is still much to sort out, including a final site-specific design and an environmental impact assessment, as well as obtaining planning permission and figuring out exactly which countries want to join. But as with other major European research facilities, choosing a site—Lund won out over rivals Debrecen in Hungary and Bilbao in Spain—is always a tense and deeply political part of the process. ESS will be "the first European experimental facility in Sweden and the first outside the big five E.U. nations," says Colin Carlile of Lund University, who headed the effort to bring ESS there.

ESS will surpass current U.S. and Japanese neutron sources in power, unless they upgrade in the meantime. Neutron beams are used by a wide variety of researchers to probe how atoms are arranged within materials and how they interact. Beams of the particles can be produced using a nuclear reactor or by smashing a proton beam into a metallic target, a process known as spallation.

In the 1990s, Europe had the top two neutron sources: a reactor in France and a spallation source in the United Kingdom. U.S. researchers at the time were facing a neutron drought after a planned reactor was canceled in 1995. But the Spallation Neutron Source in Oak Ridge, Tennessee, got the green light in 1998 and opened for business in 2007 with a 1.5-megawatt beam. J-PARC, a multi-accelerator facility in Tokai-mura, Japan, is in the process of commissioning its 1-MW neutron beamline.

Although Europe drew up plans for a 10-MW spallation source in 1995, no European government seemed to want to pick up the ball and run with it. By 2003, ESS seemed all but dead, despite a cost reduction by downgrading to 5 MW. Cywinski blames this impasse on the fact that Europe "doesn't have one doorstep on which to put a proposal." Instead, researchers have to find a government to champion their idea and build a group of collaborators, a process known in E.U. circles as "variable geometry." Says Cywinski: "Variable geometry doesn't work, or we would have had ESS years ago."

ESS finally got a shot in the arm from the European Strategy Forum on Research Infrastructures, an E.U. body that in 2006 drew up a list of facilities that would benefit European research, describing ESS as a mature project. That stamp of approval led to E.U. money for preparatory work and several countries stepping up to offer possible sites. The Swedish government, for example, offered to pay 50% of ESS's construction cost and 20% of operating expenses. The site at Lund will also be home to a new Swedish-built synchrotron, an intense source of x-rays for research, and ESS will aim to be carbon-neutral through a joint project with a wind-energy company.

Sweden worked hard to get neighboring countries in Scandinavia and the Baltic on board before the vote. The final decision was made on 28 May after a group of research ministers from 12 countries interested in participating met to discuss the bids and then the non-bidding countries voted. Seven declared they would join the Lund effort—Germany, France, Poland, Denmark, Norway, Estonia, and Latvia—and two others, Italy and Switzerland, backed the Lund site. Portugal voted for Bilbao.

Sweden must cement the collaboration over the next few months with a memorandum of understanding signed by the partners and attempt to bring Italy and Switzerland as well as defeated rivals Spain and Hungary into the collaboration. Construction is penciled in to start in 2012. –DANIEL CLERY

Research fields. An artist's impression of ESS at Lund, with the doughnut-shaped MAX IV synchrotron.

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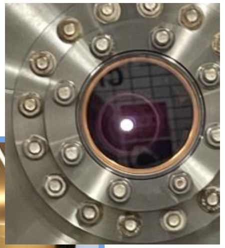
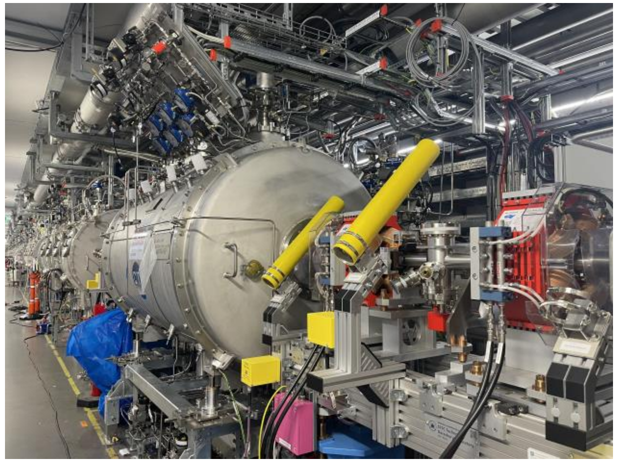
Groundbreaking

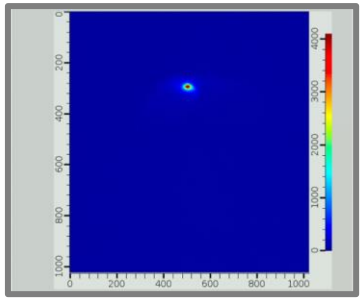
September 2014

First protons in LEBT

September 2018







First protons on dump

April 2025

First protons on Target

January 2027

End of construction

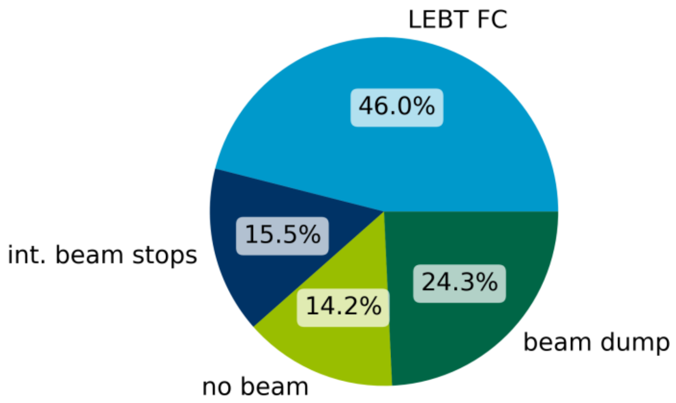
December 2027

Goals of commissioning

2025

Transport a probe beam to dump

- 800 MeV beam energy
- 6 mA beam current
- 5 us pulse length



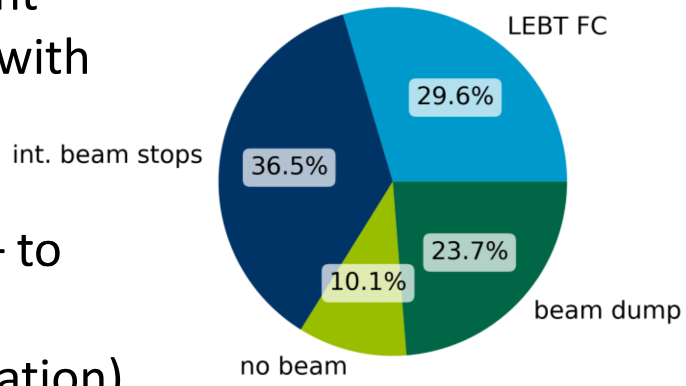
2026

~~Transport beam to target~~ → 2027

Ramp up current and pulse lengths separately at 800 MeV:

- 62.5 mA beam current – or as high as possible with acceptable losses

-Longer pulse length – to verify RF stability
(piezos enter the equation)



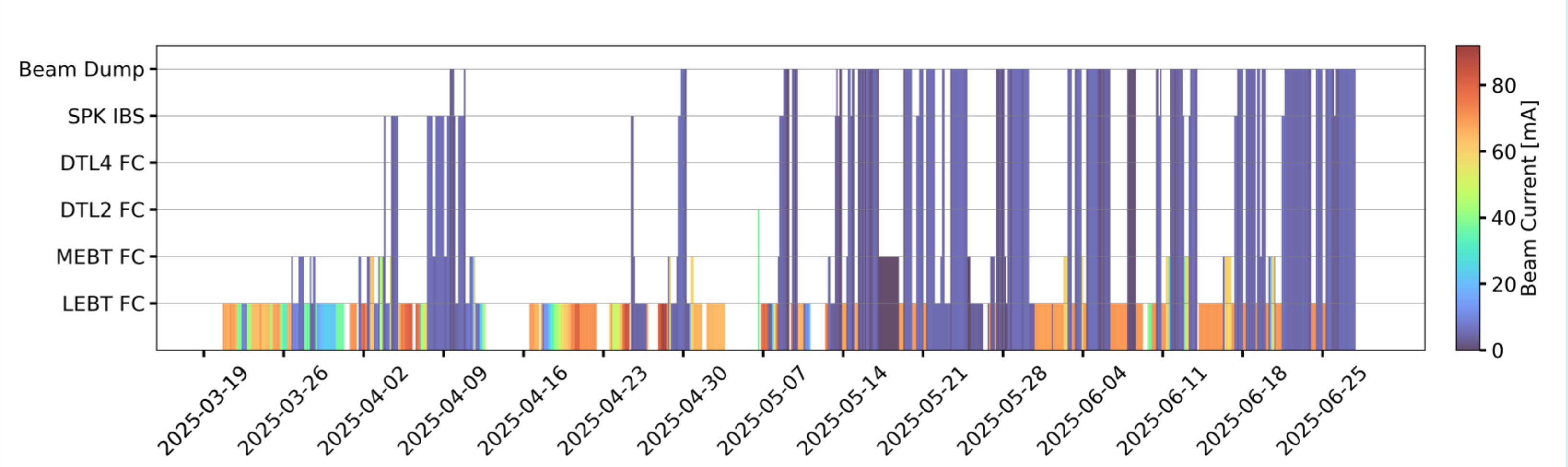
Timeline of the two commissioning periods

2025 (Mar-June)

Started March 20th

Limited to 5 us pulse length

Two months to accelerate beam to dump TBD

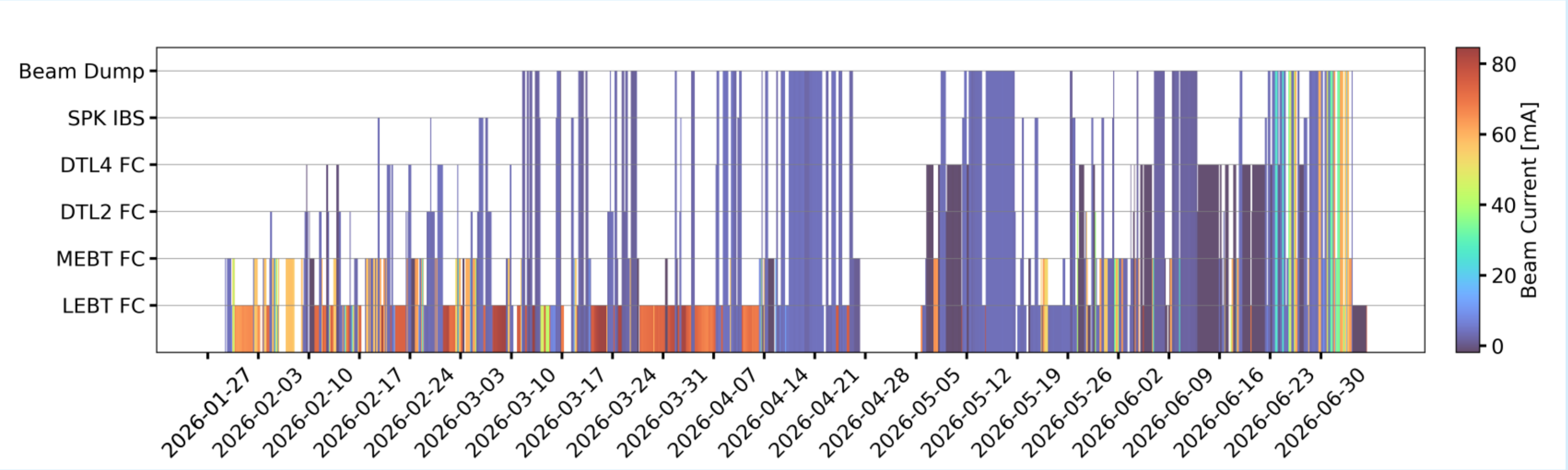


2026 (Jan-June)

Started January 28th

Reached dump (90 MeV) in March

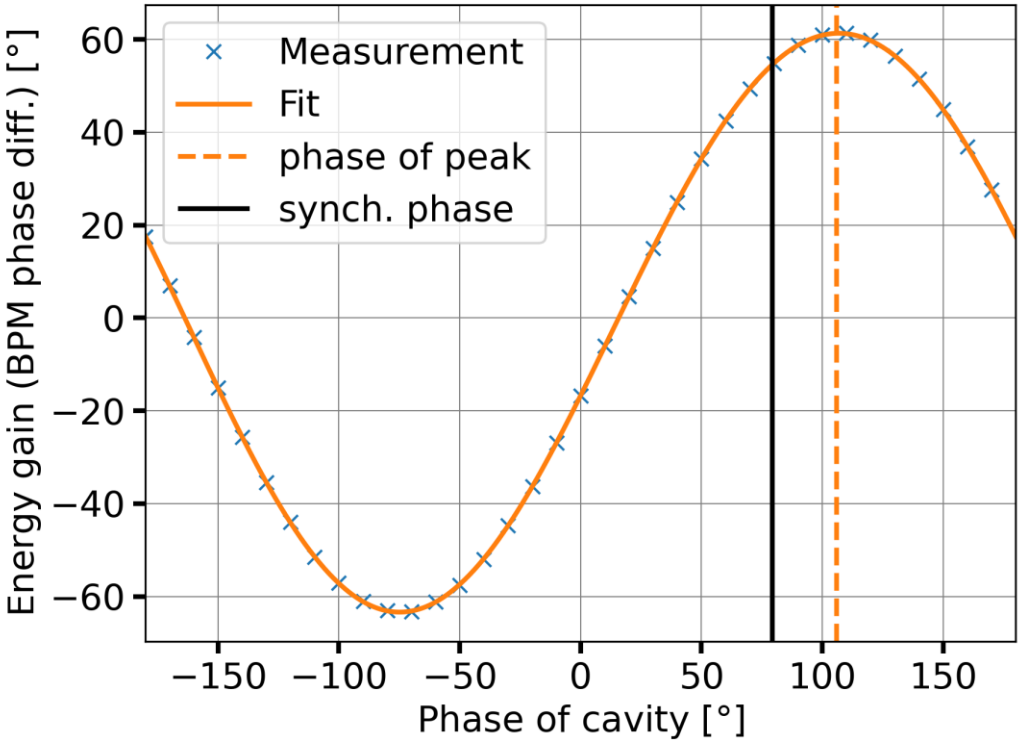
20 mA 1500 us beam to dump



Longitudinal Tuning

Phase scans of

- 3 buncher cavities
- 5 DTL tanks
- 26(-1) SPK cavities
- 36 MBL cavities
- 20 HBL cavities



- Scan the phase of cavity 360°
- Fit to simulated data to get: amplitude and set phase for nominal energy gain
- Good convergence achieved after two iterations.

Sometimes, arcdetectors of downstream cavities needed to be disabled – still using probe!
Tried scanning with 1 mA beam – too much characteristic changes to 6 mA

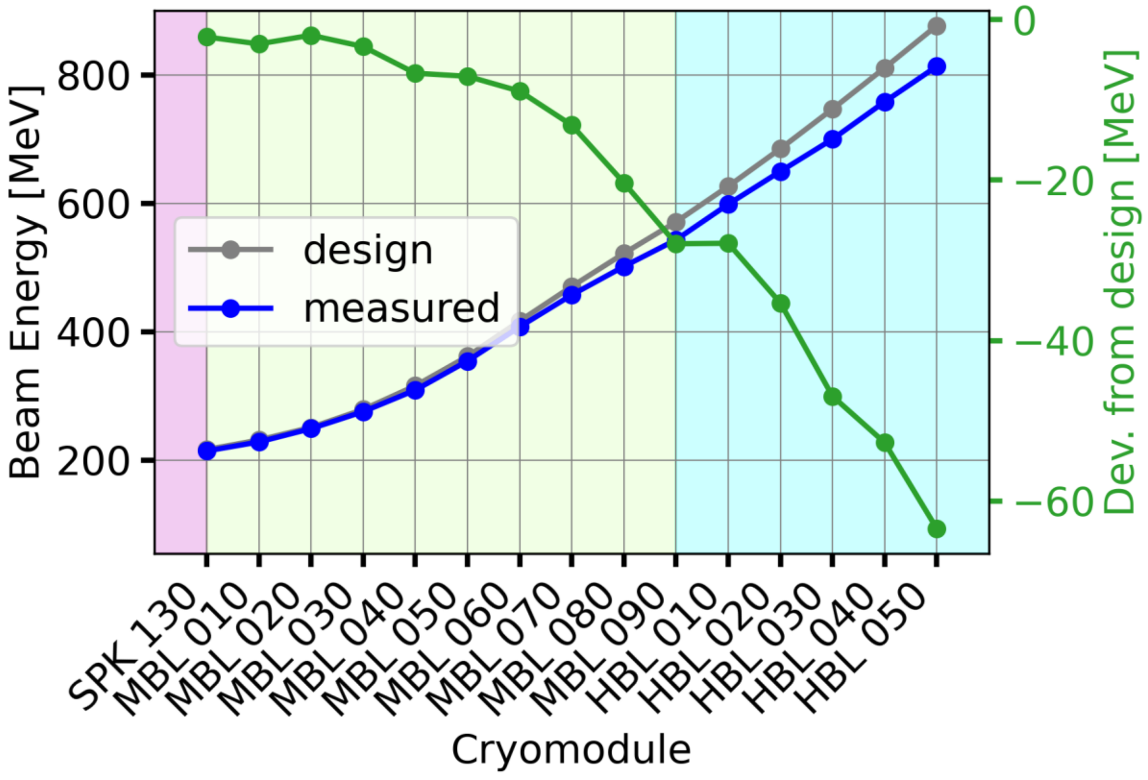
Courtesy of D. Noll, see THPO002

Energy measurements

2025

Could measure energy using a fast oscilloscope installed at two places in HEBT

- Could only measure energy from the first MBL

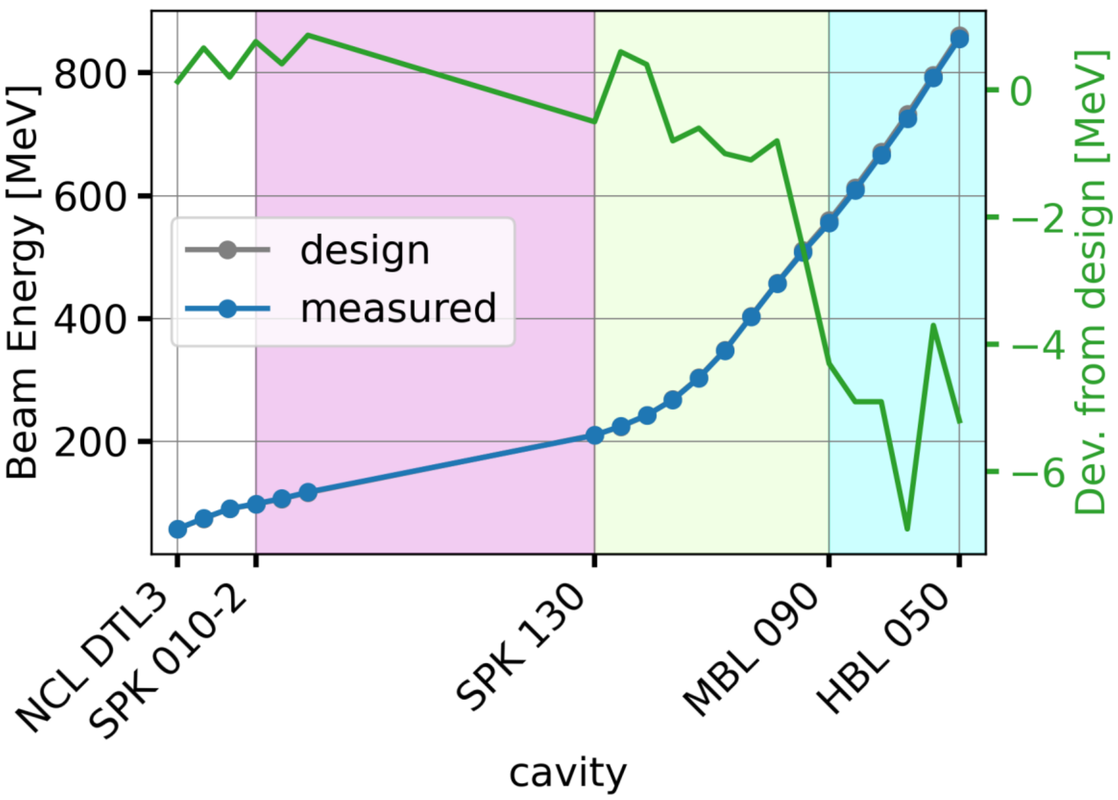


2026

New energy measurement available in SPK.

Energy corresponds to baseline without SPK-070 1

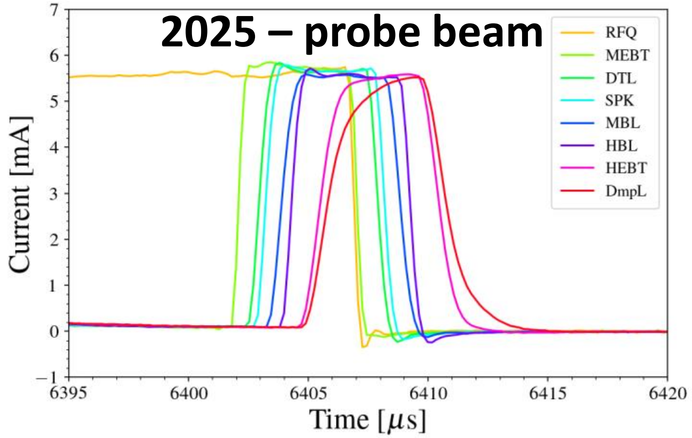
see TH1A004 for more details



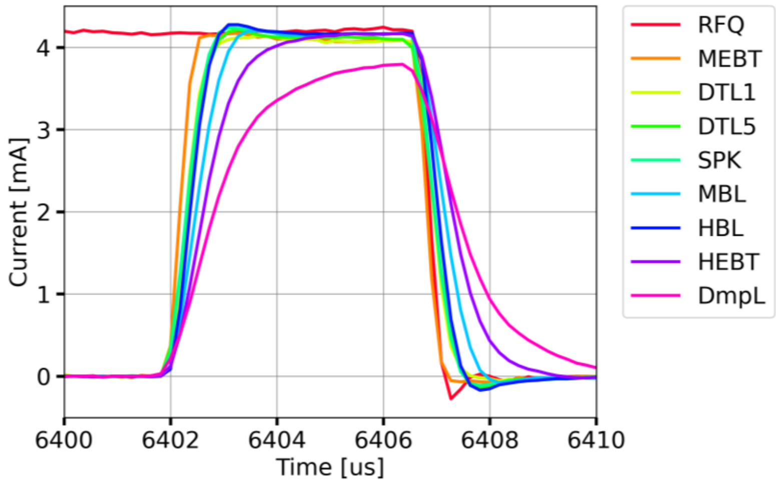
Transmission

Plot BCM signals for 8 different locations along the accelerator
2025: good transmission for 20 W

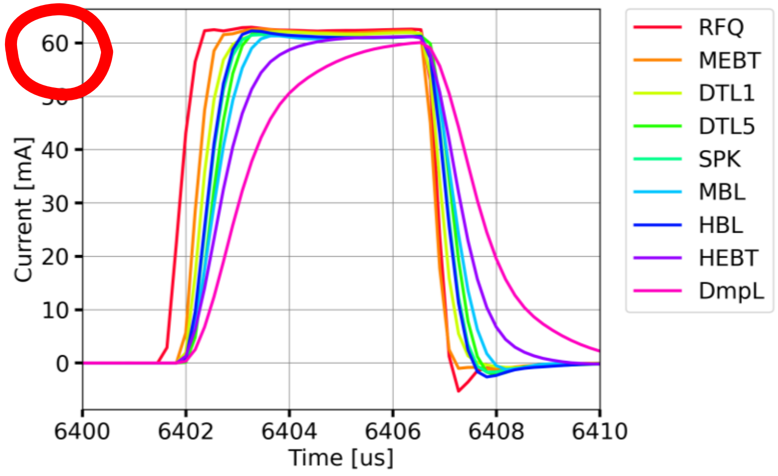
2026: Excellent transmission
- even without superconductive cavities (2 W)
- for a 60 mA, 5us beam (260 W)
- for a 30 mA, 5 us beam (1.3 kW)



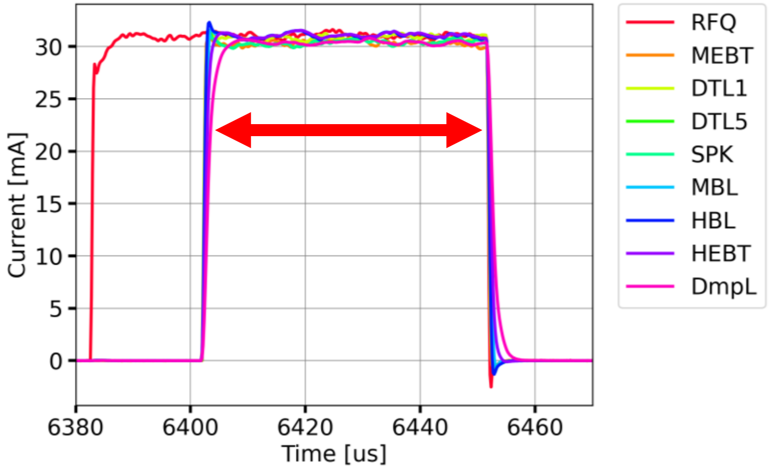
90 MeV



62.5 mA



50 us



Transmission

Transported a 20 mA, 1500us beam at 870 MeV!
At a repetition rate of1/30 Hz

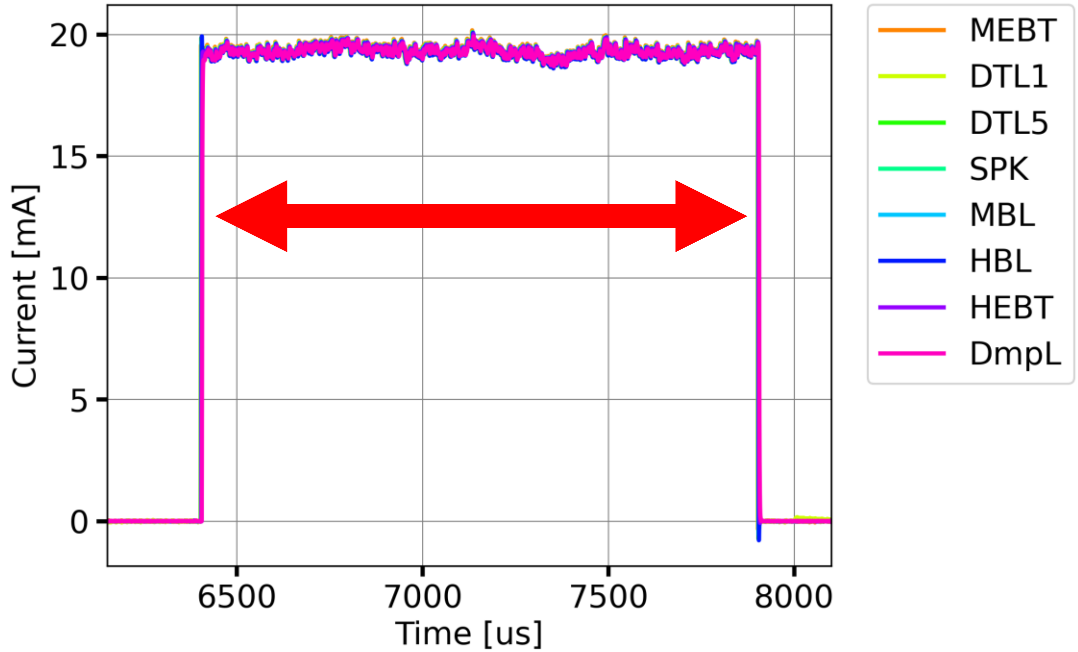
Equivalent to a 360 kW beam at full repetition rate

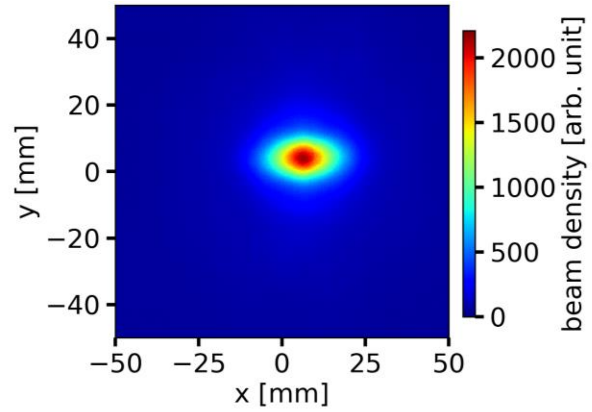
Given the BCM accuracy, we have good transmission

see TUPO036 for more about the BCMs

More accurate measurements with BLMs are planned

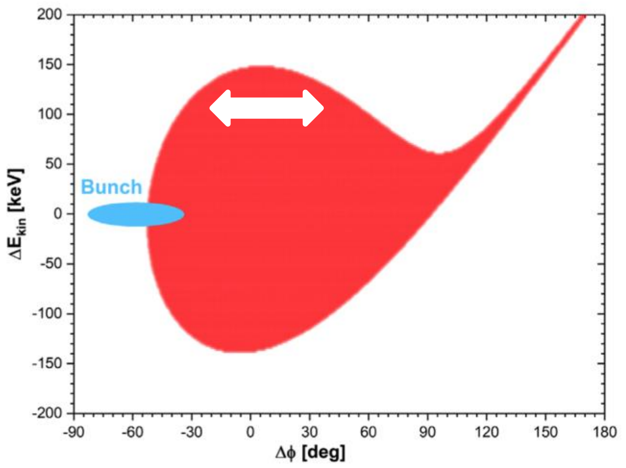
see MOPO066 and TUPO024 for more about BLMs





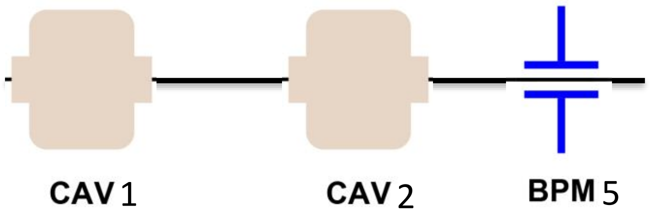
Longitudinal Beam Parameters MEBT

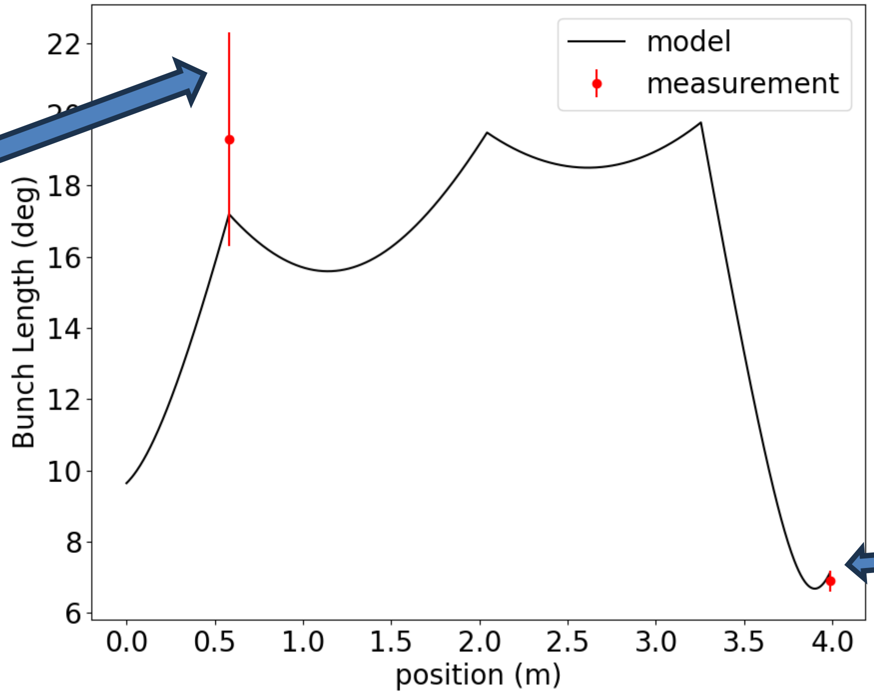
Move DTL1 phase e observe transmission

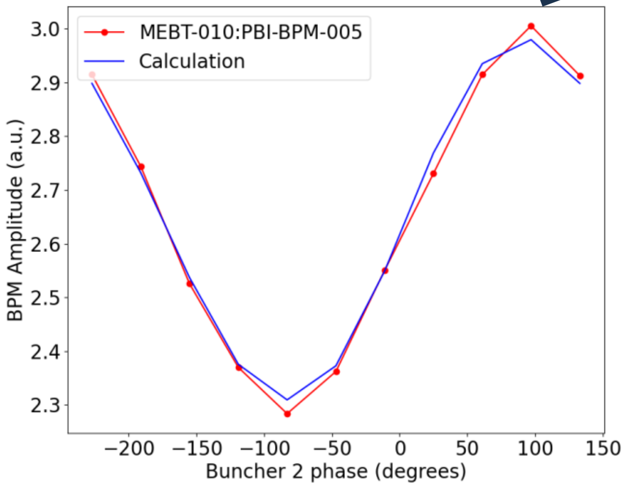


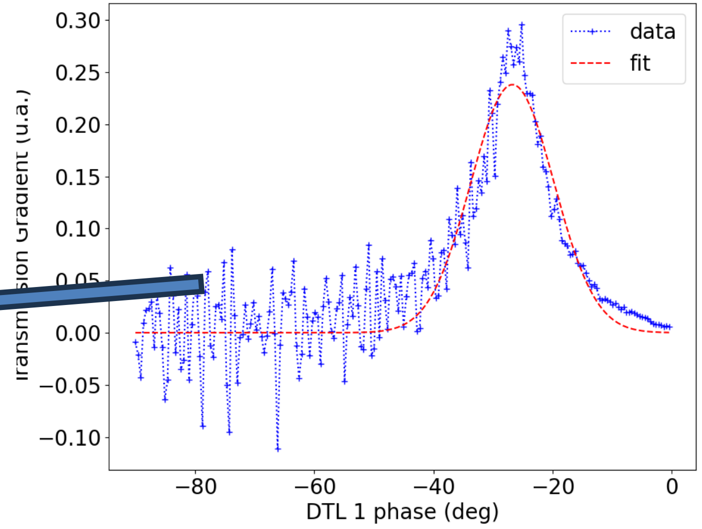
Used Shishlo Method (PRSTAB, 16)

PRELIMINARY RESULTS









Model with a longitudinal emittance increased **3 fold**

Transverse tuning - trajectory

Trajectory corrected using steerers along the accelerator

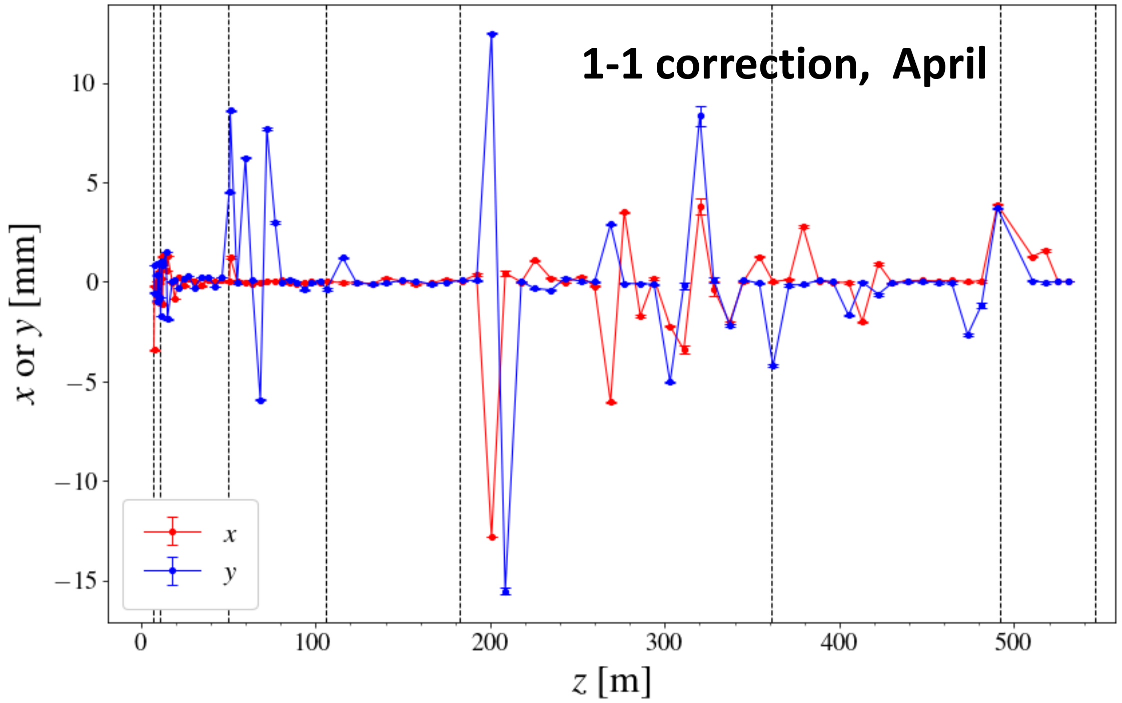
1-to-1 correction: sequential corrector–BPM tuning

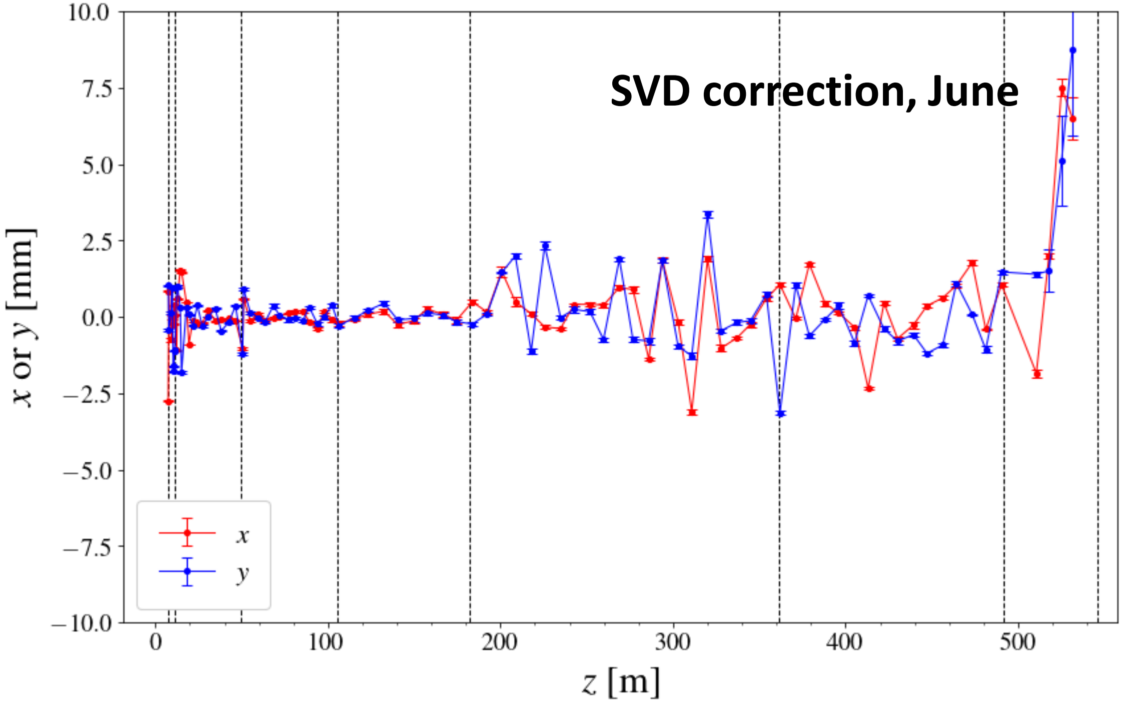
Some BPM signals appear artificially amplified – fixed for some BPMs!

SVD correction

Response matrix measured for SCL looks good, no big elements on the top right as expected

Dumpline BPMs have large aperture – cannot trust the signal completely





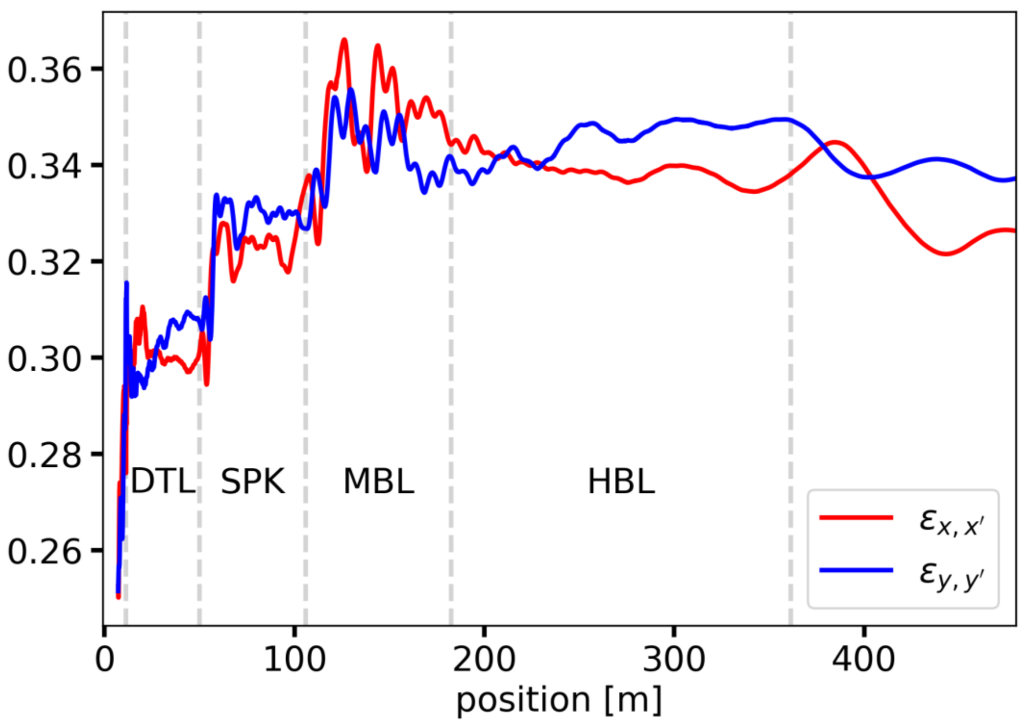
Transverse emittance

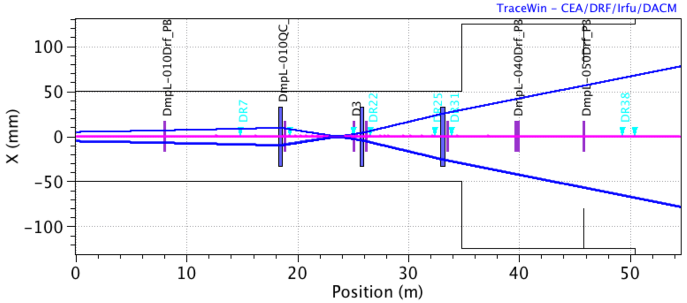
Compare emittance in MEBT to emittance in Dumpline

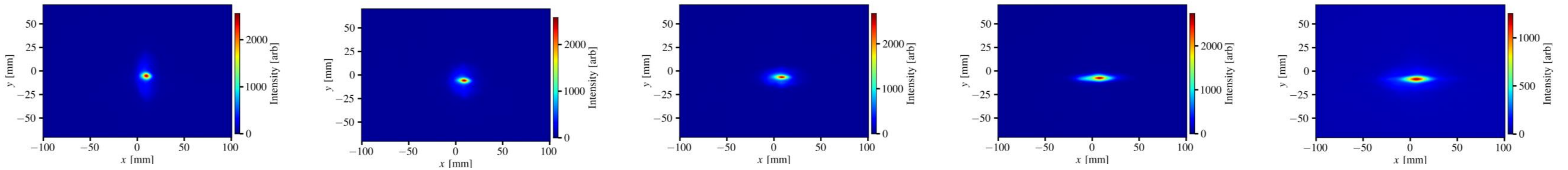
Emittance stays similar for low beam current

Emittance growth for high current - expected

		H (6 mA / 60 mA) [mm mrad]	V (6 mA / 60 mA) [mm mrad]
MEBT	EMU Quad scan	0.11 / 0.23 0.3 / -	0.10 / 0.21 0.045 / 0.37
Dmpl	Quad scan	0.11 / 0.69	0.16 / 0.48







Summary and Conclusions

2025

- The commissioning run of 2025 was successful
- Reached target beam energy of >800 MeV for a beam of 6 mA, with a pulse length of 5 us at a repetition rate of 1 Hz
- 22 W beam

2026

- More beam instrumentation has been available
- 20 mA, 1500 us beam transported to beam dump. (Equivalent of 360 kW beam in one shot)
- 62.5 mA at 5 us also transported to beam dump.
- Improved models and hardware – better outcome of phase scans
- 1.5 kW beam

To do in fall:

- ➢ Send production beam to dump (at 1/30 Hz)
- ➢ Characterization of longitudinal phase space
- ➢ Evaluate reliability and stability of high-power beams

→ **Send beam to Target in early 2027!**

ESS contributions to LINAC 2026

Emmanouil ESS Ion Source and LEBT Test Stand THPO020

Marten Technical commissioning of the ESS linac cavities for the Beam on Dump Phases TH1A004

Slava Status update on ESS ICBLM detector Xray tests TUPO024

Hooman ESS Beam Current Monitor System: Technical Challenges and Improvements from Seven Years of Operation TUPO036

Sofia Emittance investigations at the ESS LINAC MOPO038

Aga Maintenance strategies and high-power RF testing of ESS RFQ power couplers and DTL RF windows TUPO043

Andrea Plasma Processing Developments for Medium- and High-Beta Cavities in the ESS Linac TUPO045

Daniel Phase and Amplitude Setup of the RF Cavities of the ESS Linear Accelerator THPO002

Sofia Beam commissioning of the ESS accelerator: Results and Challenges MO2A002 (edited)

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Thank you for your attention!

Questions?