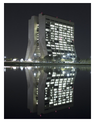
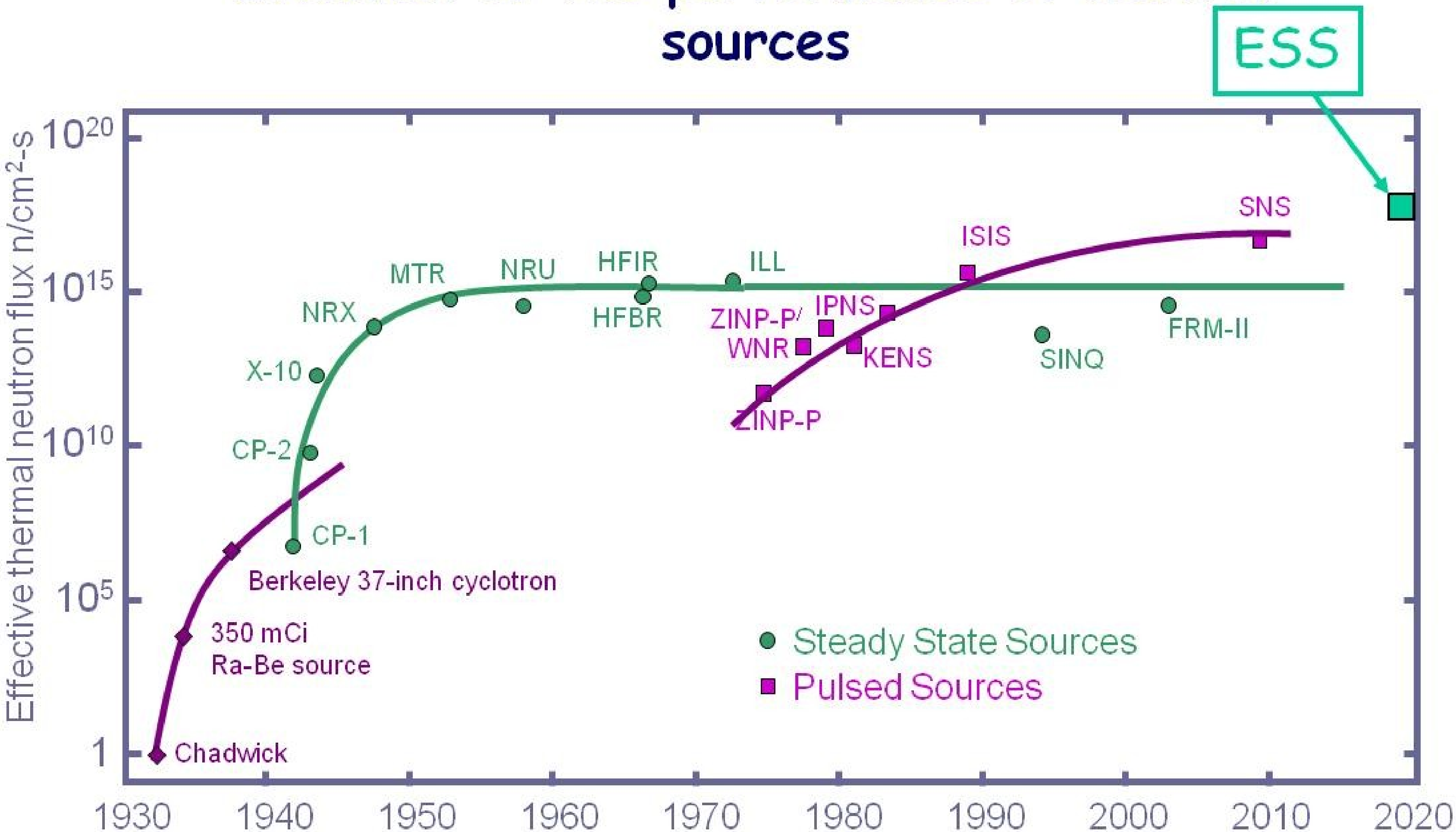


The ESS Linac

Steve Peggs, Mats Lindroos, Cristina Oyon

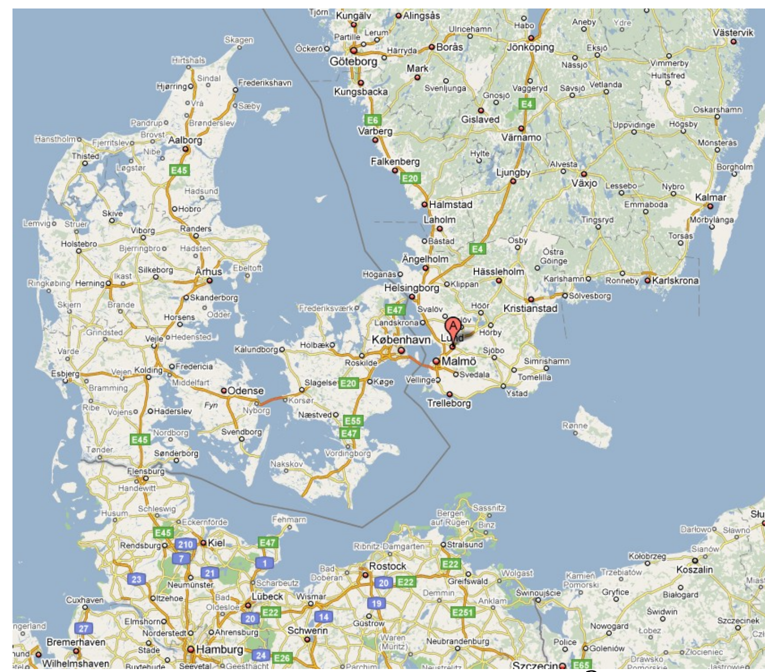
Evolution of the performance of neutron sources



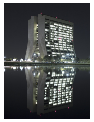
(Updated from *Neutron Scattering*, K. Skold and D. L. Price, eds., Academic Press, 1986)

OECD: "A High Power Spallation Source in each Global Region"

Lund!



ESS process



Three consortia bided for the site (Bilbao, Lund & Debrecen)

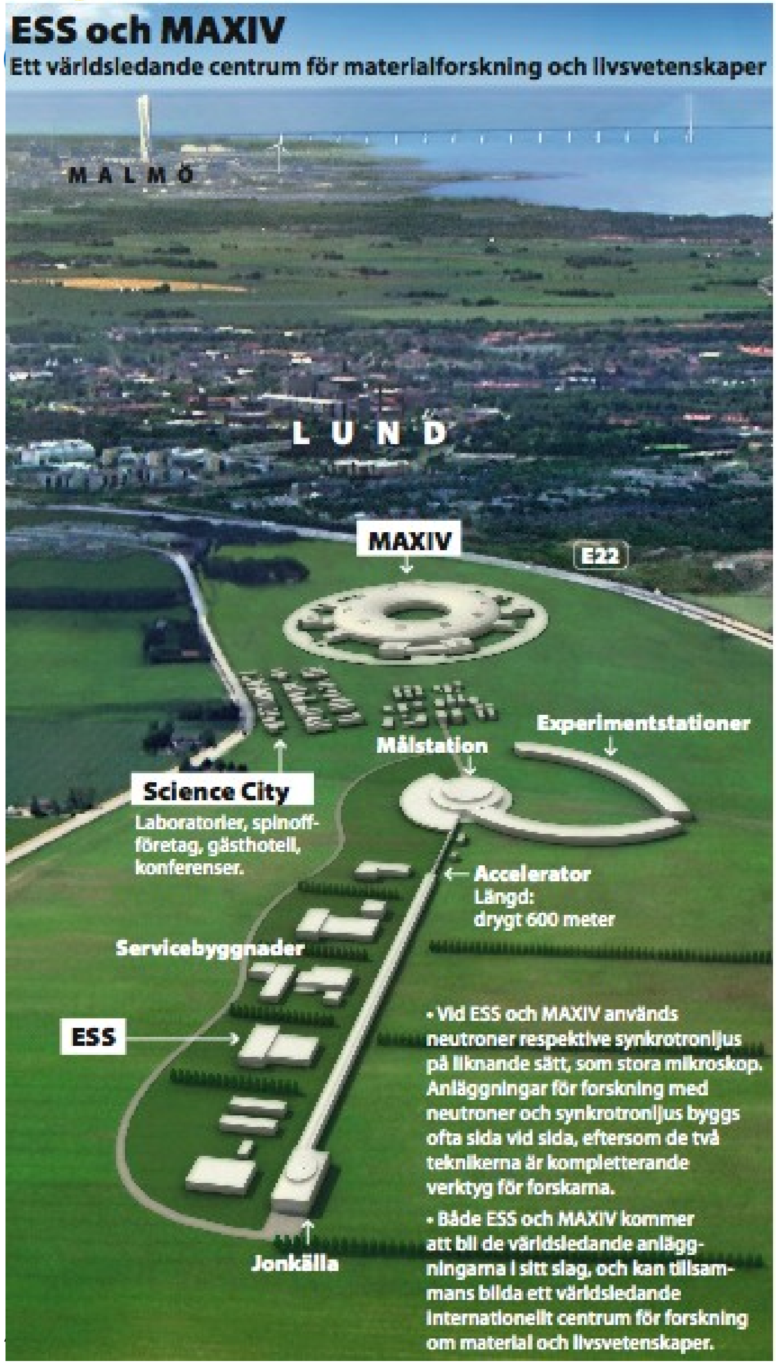
May 2009: Lund proposed as ESS site with important contributions and supporting infrastructure in Spain

Oct 22-23: First Steering Committee meeting in Copenhagen.

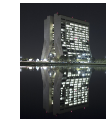
Jan 2010: Form “ESS Corporation”, with 13 (+ more?) countries as shareholders

Now: Integrate ESSB and ESSS accelerator & target teams

2012: Update the 2003 “Volume III Update” design to a Technical Design Report by end of 2012.



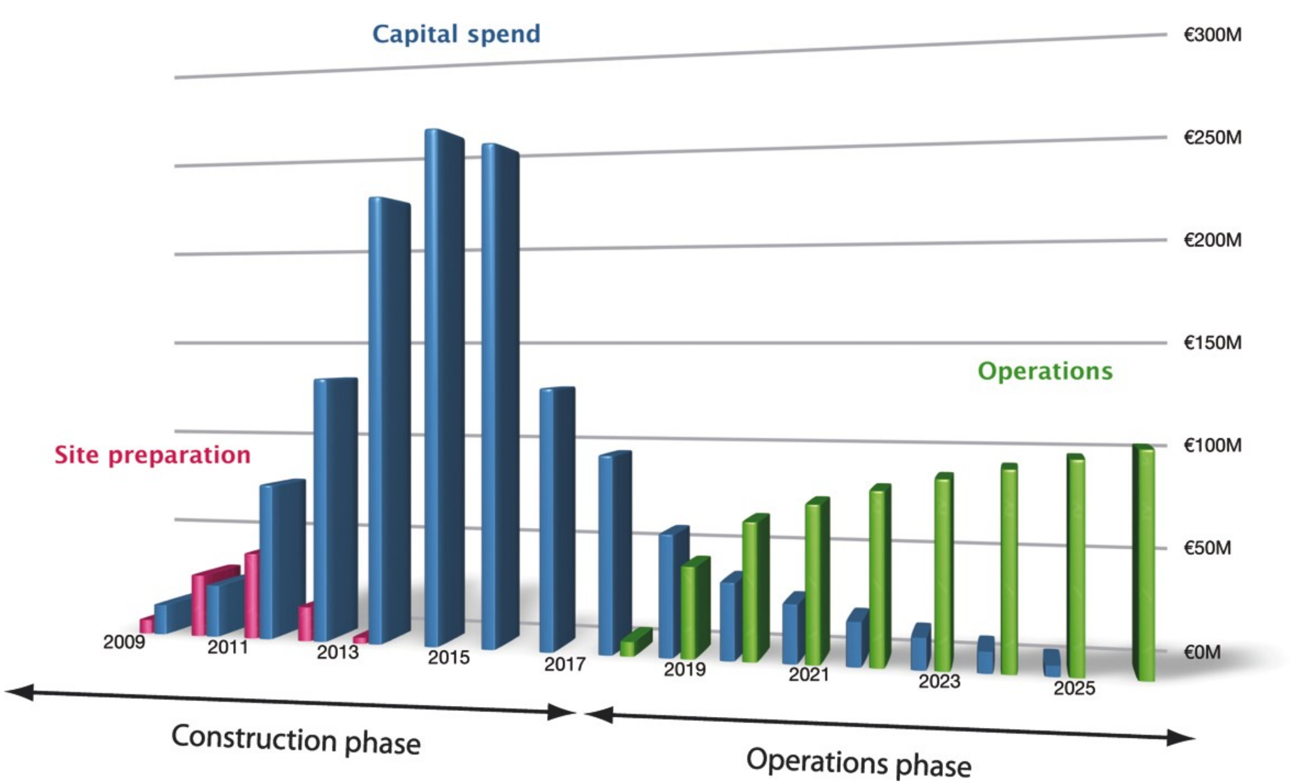
Primary parameters



5 MW long pulse source
(upgrade to 7.5 MW?)

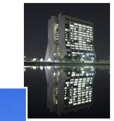
≤ 2 ms pulses
≤ 20 Hz
Protons (H+)
Low losses ! 1 W/m
High reliability, >95%

Budget

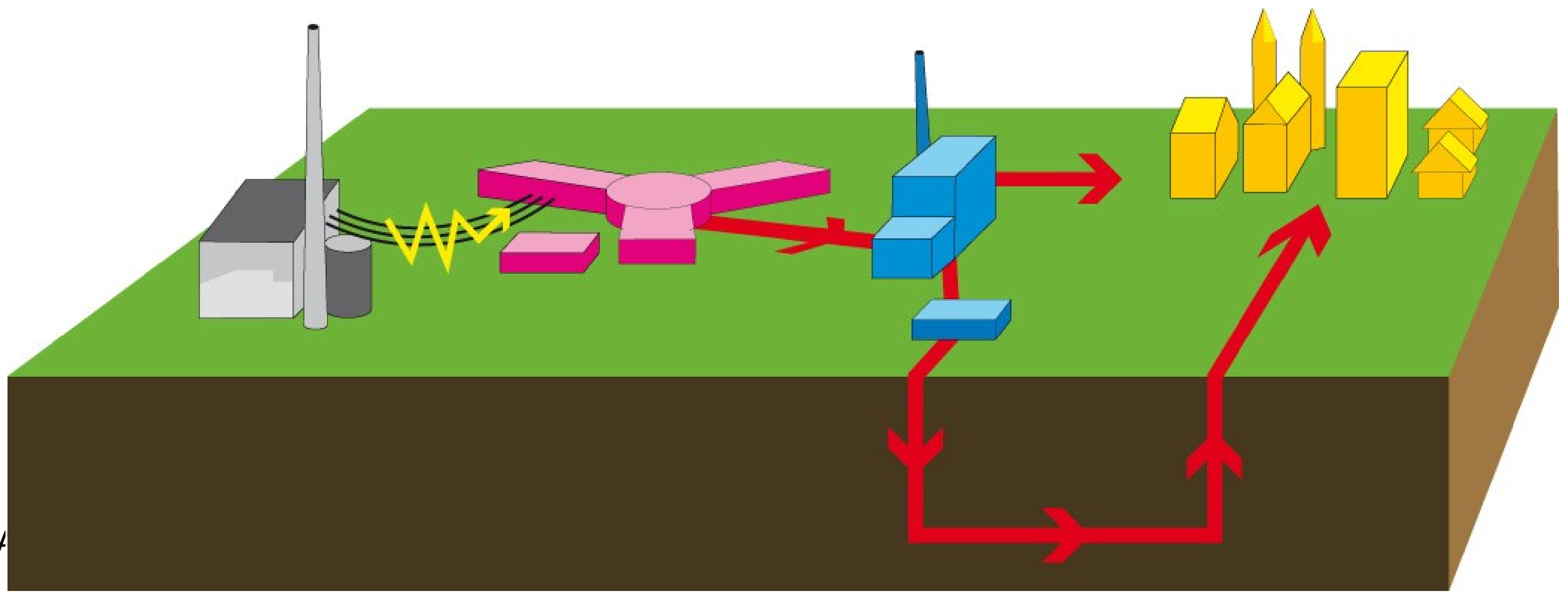


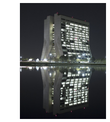
Facility investment: 1.377 M€$_{2008}$ with 22 instruments
+ 101 M€$_{2008}$ site specific cost
Operational cost: 89 M€$_{2008}$ per year
Decommissioning cost: 344 M€$_{2008}$

Climate neutral



Heat homes, offices & businesses, not the atmosphere,
Save ~ 4M€ p.a.

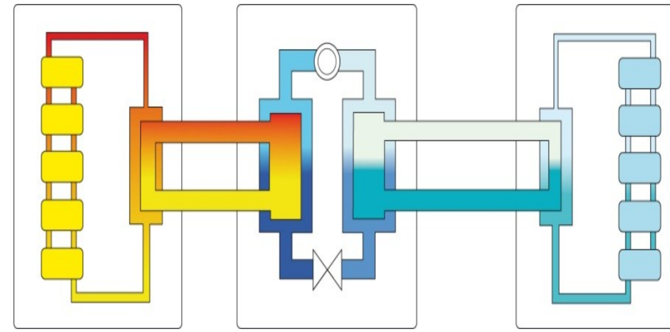


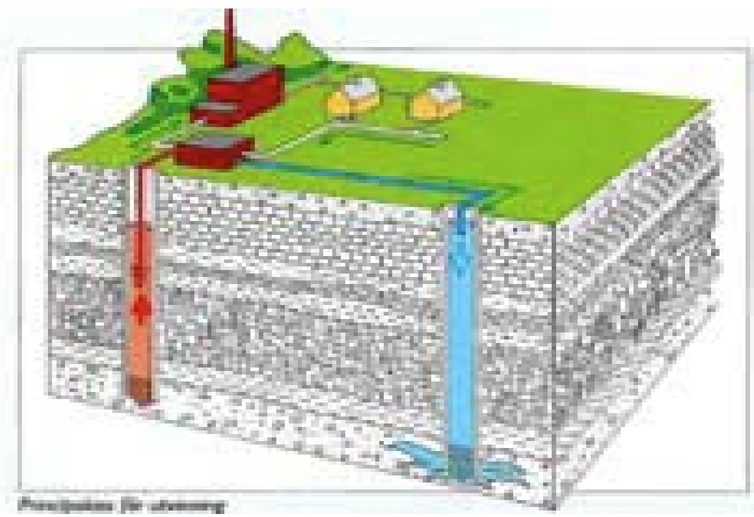


Integration into the Lund District Heating & Cooling System

Heat exchangers, not cooling towers!

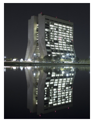
→



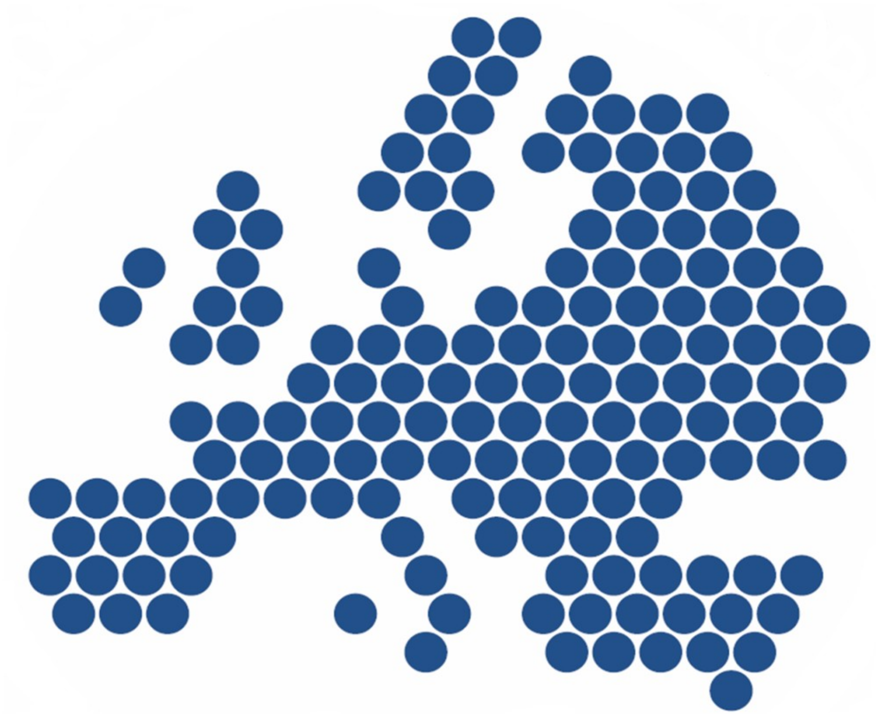


Store heat over summer in the aquifer (80 C → 60 C)

Design update: ESS-Bilbao Preparatory work

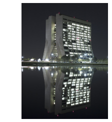


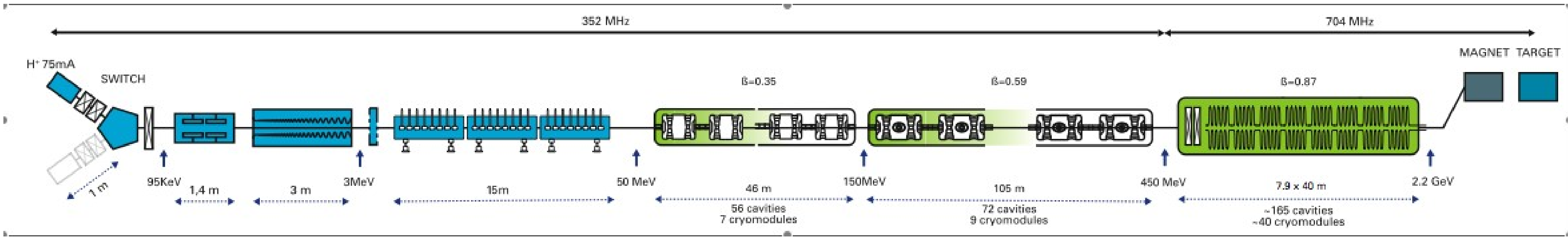
ESS-Bilbao WORKSHOP PARTICIPANTS



The workshop brought together more than ***160 experts*** *from across the world, leaders in the fields of* ***high power proton accelerators***, ***beam dynamics and targets***, *in a format and infrastructure that promoted open discussion, while maintaining the focus of documenting clear* ***recommendations*** *for* ***future collaborative R&D efforts***.

ESS-Bilbao WORKSHOP ACCELERATOR COMPONENTS

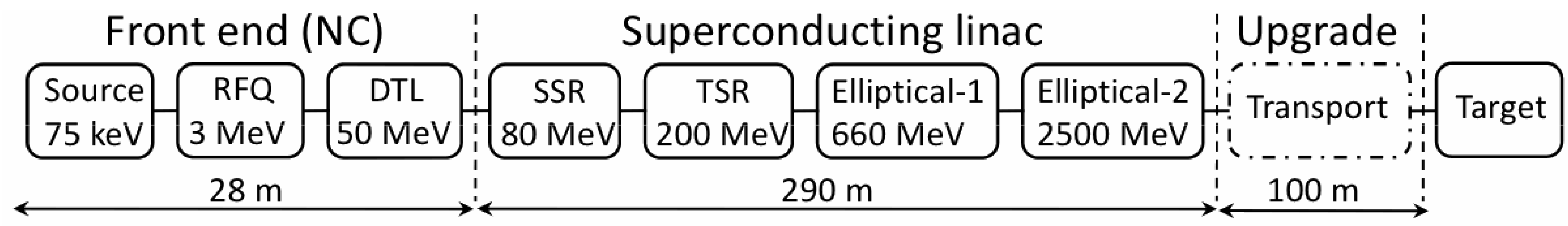




*In comparison to the originally proposed design (5 MW, 1 GeV, 150 mA, 16.7 Hz) <u>the parameters have been modified</u> in order to **simplify the linac design** and to **increase reliability**. In essence the current has been decreased and the final energy has been increased, keeping the footprint of the accelerator the same.*

- ✓ ***Increase in energy** – With increased energy the average pulse current can be reduced by the same factor.*
- ✓ ***Increase of the cavity gradient** – By decreasing the current to 75 mA, the gradient can be raised to 15 MV/m, keeping the coupler power constant at 1.2 MW.*
- ✓ ***Increase of beam energy** - the final energy was increased from 1 to 2.2 GeV.*
- ✓ ***Repetition rate** - The originally proposed repetition rate of 16.67 Hz has been increased to 20 Hz.*
- ✓ ***Pulse length** - The originally proposed pulse length of 2 ms has been reduced to 1.5 ms*

ESS-S building blocks & parameters



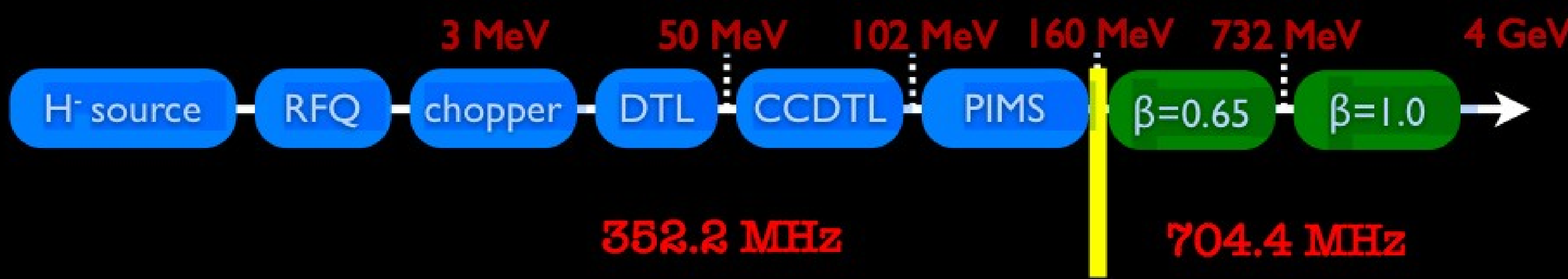
INPUT		B		S
Average beam power	[MW]		5.0	
No. of instruments			22	
Macro-pulse length	[ms]	1.5		2.0
Pulse repetition rate	[Hz]		20	
Proton kinetic energy	[GeV]	2.2		2.5
Peak coupler power	[MW]	1.2		1.0
Beam loss rate	[W/m]		<1.0	
OUTPUT				
Duty factor		0.03		0.04
Ave. current on target	[mA]	2.3		2.0
Ave. pulse current	[mA]	75		50
Ion source current	[mA]	$\sim$90		60
Total linac length	[m]		$\sim$420	

System	T [K]	Energy [MeV]	Freq. [MHz]	β v/c	Length [m]
Source	300	0.075	–	–	2.5
LEBT	300	–	–	–	1.1
RFQ	300	3	352.2	–	4.0
MEBT	300	–	352.2	–	1.1
DTL	300	50	352.2	–	19.2
SSR	4	80	352.2	0.35	23.3
TSR	4	200	352.2	0.50	48.8
Ellipt-1	2	660	704.4	0.65	61.7
Ellipt-2	2	2500	704.4	0.92	154.0

Synergies with SPL

SPL construction, stage 2:

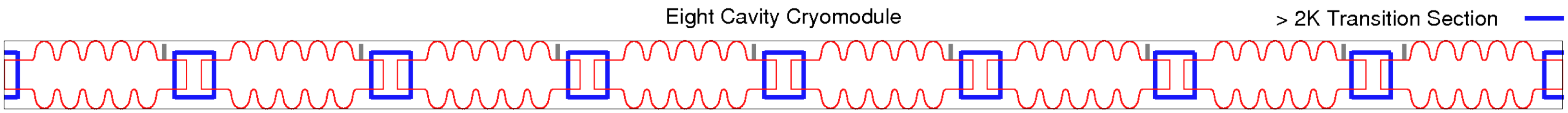
LP-SPL (4 GeV)



- construction of Low-Power SPL together with PS2,
- main users: PS2 (LHC), ISOLDE upgrade, EURISOL-0 (?),
- operation in 2020

kinetic energy	4 GeV
beam power (@ 4 GeV)	0.14 MW
repetition rate	0.6 - 2 Hz
pulse length	0.9 ms
average pulse current	20 mA
protons p. pulse	$1.1\ 10^{14}$
length (SC linac)	427 m

704 Mhz elliptical cryomodules



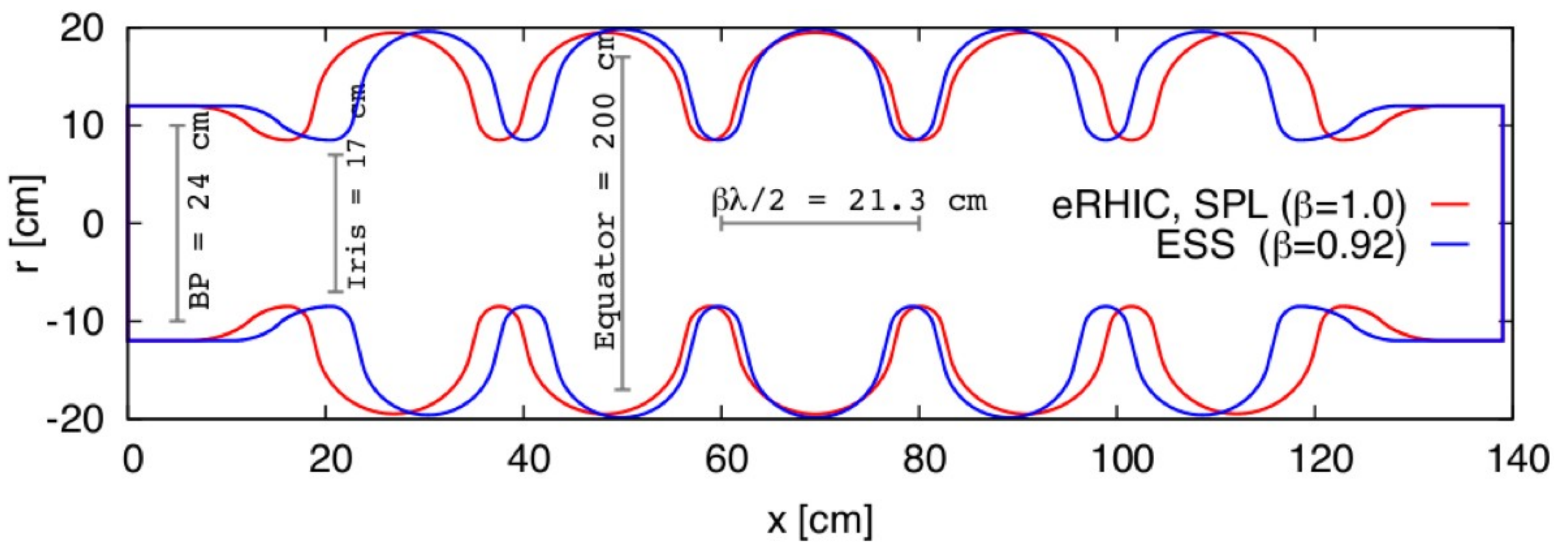
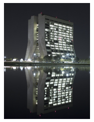
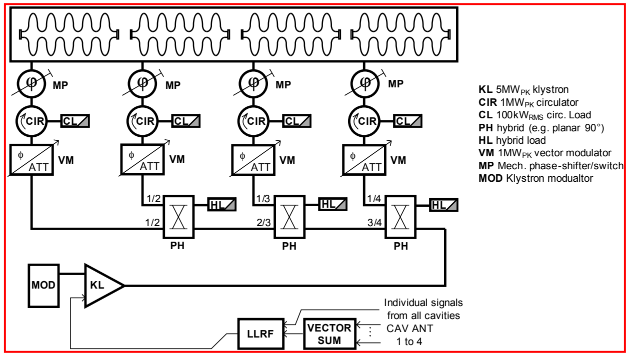
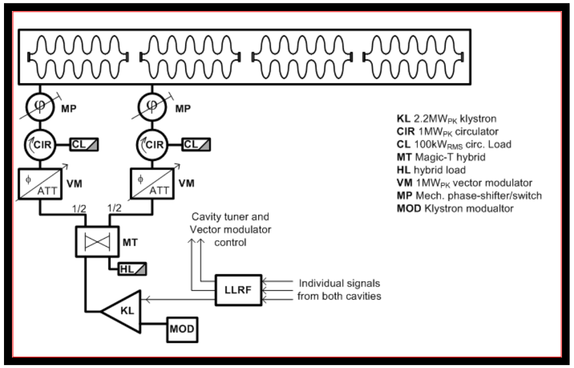


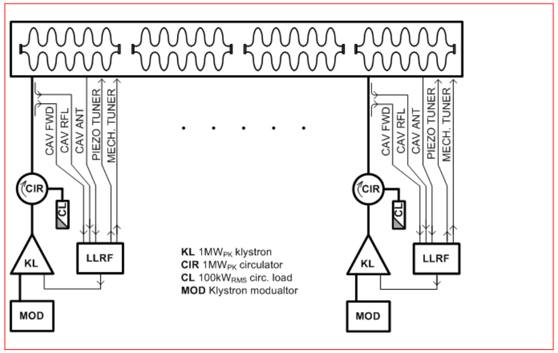
Figure 2: The five-cell 704 MHz cavity, showing the similarities between ESS, SPL and eRHIC structures.



RF distribution



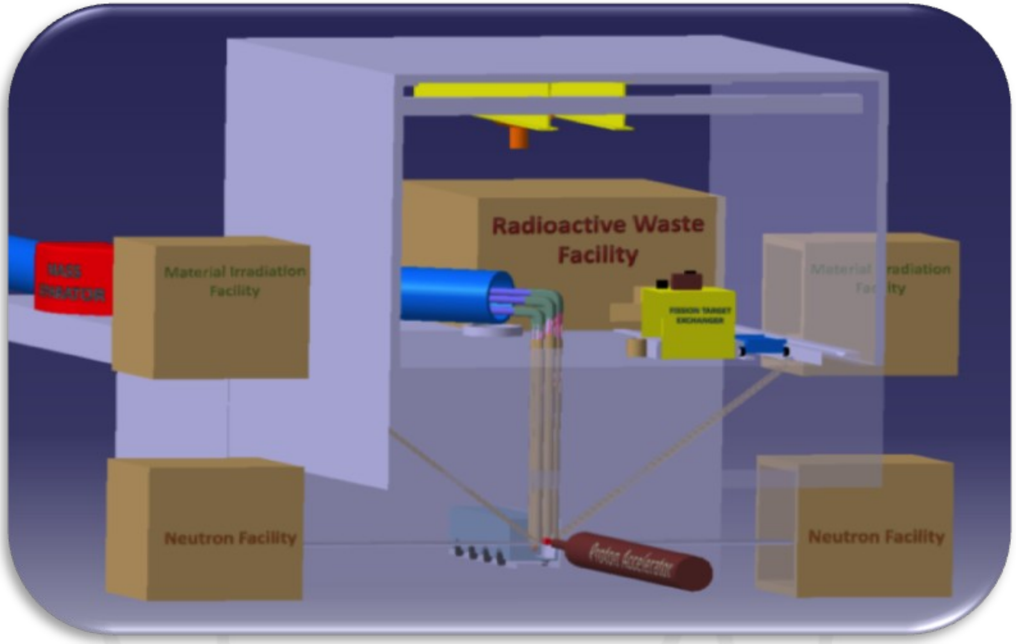




Option	Configuration	Cost of 4 cavity (K-Euro)	For	Against
1	Four cavities per Klystron	2420	Fewest power sources	Complexity, bulk, power overhead, fault tolerence
2	One Cavity per Klystron	2880	Reduced hardware inventory, minimum R&D, fully independent control, minimum RF power overhead, best fault tolerance, easy upgrade to HPSPL	Number of power sources
2a	One cavity per IOT	2520	As above, perhaps cheaper & more compact	HPSPL would need doubling of IOTs, or larger rating IOTs
3	Two cavities per Klystron	2520	Half the number of klystrons	Need full hardware set, associated R&D, Power overhead, Reduced flexibility wrt option 2
3-VM	Two cavities per Klystron Without VMs	2370	Half the number of klystrons, more economical than Option 3	Risk for higher intensity?

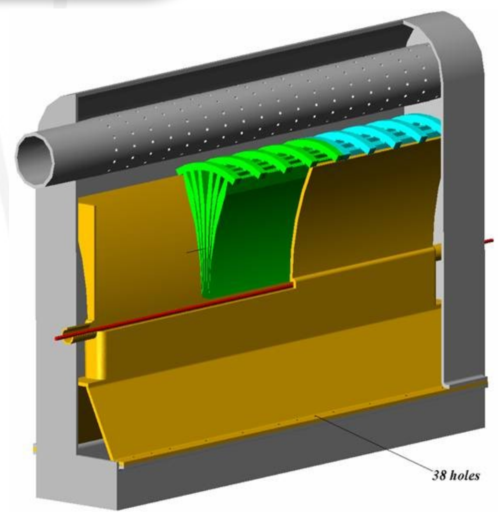
AH

Target synergies

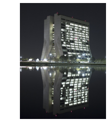


ABOVE: The EURISOL conceptual multi MW fission target design approved by International Review Panel

RIGHT: New type of window less liquid curtain neutron converter proposed



Collaboration model required!

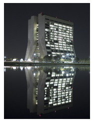


A collaboration team to share interesting R&D, assure an all European effort, and kick start the ESS work

A strong core team in Lund to take ownership, to assure cost control, and to be responsible for project integration

Work Packages

1. Management Coordination
2. Beam Physics
3. Infrastructure Services
4. SCRF Spoke cavities
5. SCRF Elliptical cavities
6. Front End and NC linac
7. Beam transport, NC magnets and Power Supplies
8. RF Systems



Modeling & Simulation

"The philosophers have only interpreted the world, in various ways; the point, however, is to change it"

"Invert the matrix" to make simulations useful as design tools.

For example:

- Robust response to a lost cavity?
- Allowable cavity strength fluctuation from the average?
- Required tuning & msmt accuracy, eg cavity phases?

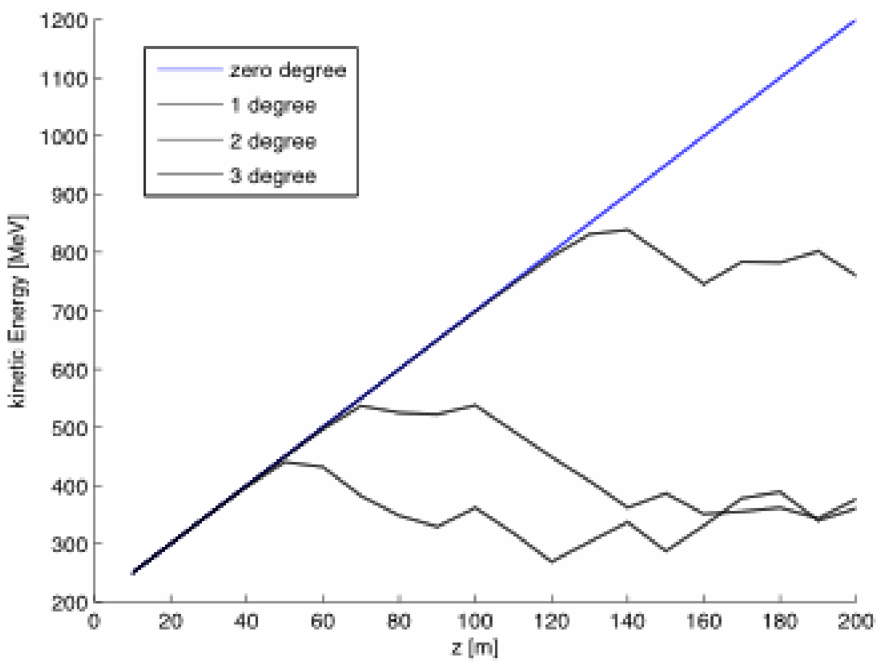
"Single particle interacts with core" dominates the dynamics?

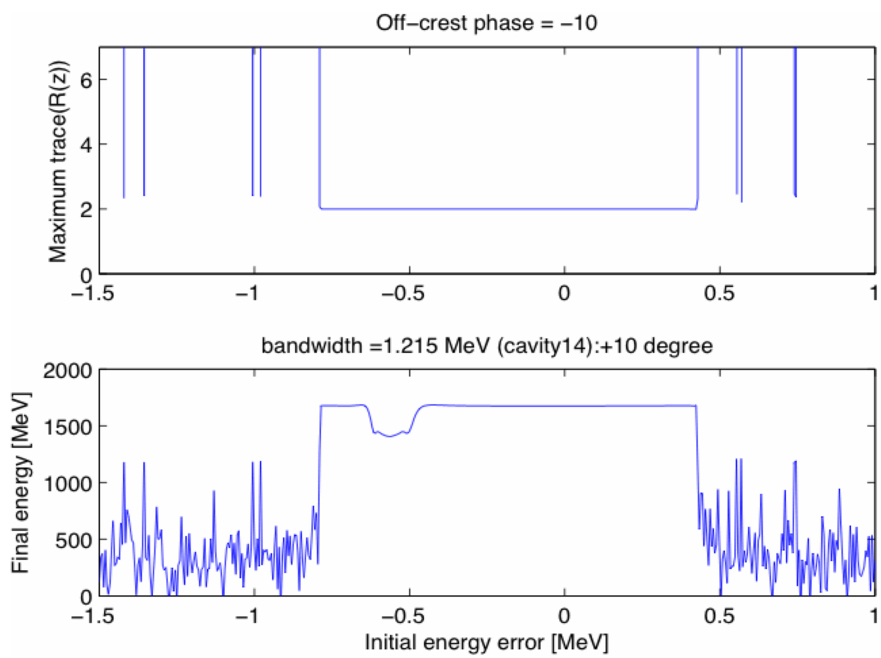
Beam losses: reductionist view

Energy Profile and Transverse Single Particle Stability in Proton Linear Accelerators

V. Ziemann
Department of Physics and Astronomy
Uppsala University, Uppsala, Sweden

Draft of September 27, 2009





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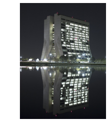
SNS view



Measurement of longitudinal acceptance and emittance of the Oak Ridge Spallation Neutron Source Superconducting Linac

Y. Zhang,* J. Galambos, and A. Shishlo
Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, Tennessee 37831-6461, USA
(Received 19 May 2008; published 8 October 2008)

"... the longitudinal rms emittance is approx. twice that of the nominal design."

acceptance. However, when particles fall out of the SCL longitudinal acceptance, as in the case of halo particles, they are no longer accelerated in the linac, and not matched to the downstream quadrupole lattice which is designed for the fully accelerated particles, and consequently, they are lost in the SCL due to transverse mismatch [7].

[7] Y. Zhang, S. Henderson, and D. Jeon, SNS Technical Note (2005).

acceleration from 391 to 1000 MeV. The medium beta cavities have a design gradient of 10.2 MV/m and the high beta cavities have a design gradient of 15.9 MV/m. In practice, the cavities have a large spread in gradients, ranging from 8 to 18 MV/m, and many high beta cavities are below the design gradient. In addition, typically several SC cavities are disabled for various reasons. The SCL cavity average synchronous phase is set at −20.5° for the cases discussed here.

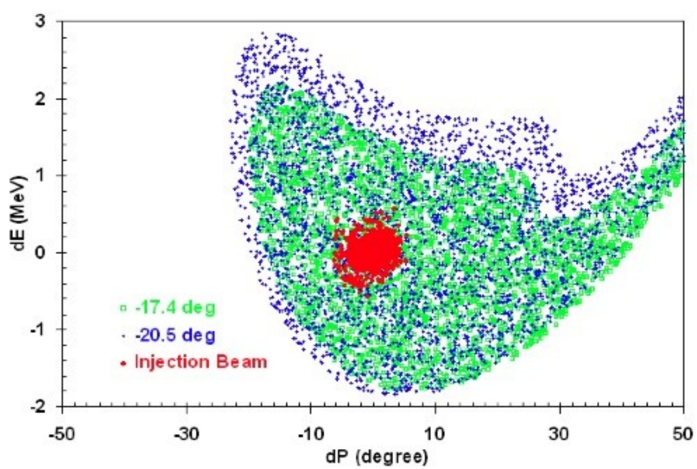


FIG. 1. (Color) Longitudinal acceptance of the SCL with an average synchronous phase of −17.4° (green squares) for each medium beta cavity and −20.5° (blue dots), an injection beam emittance with tails 6 times greater than the nominal beam is shown (red dots) for comparison.

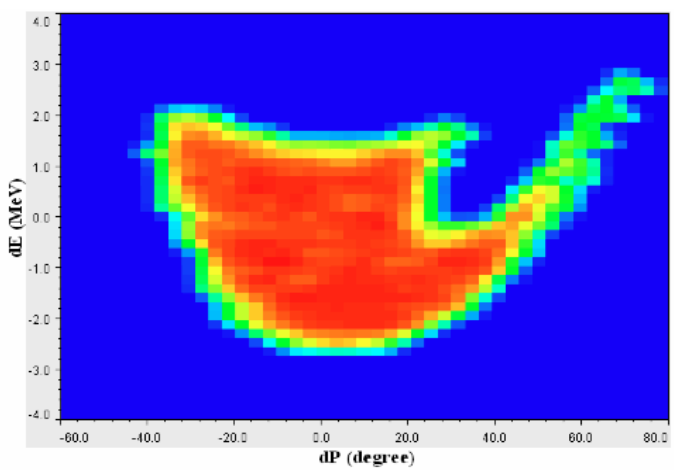
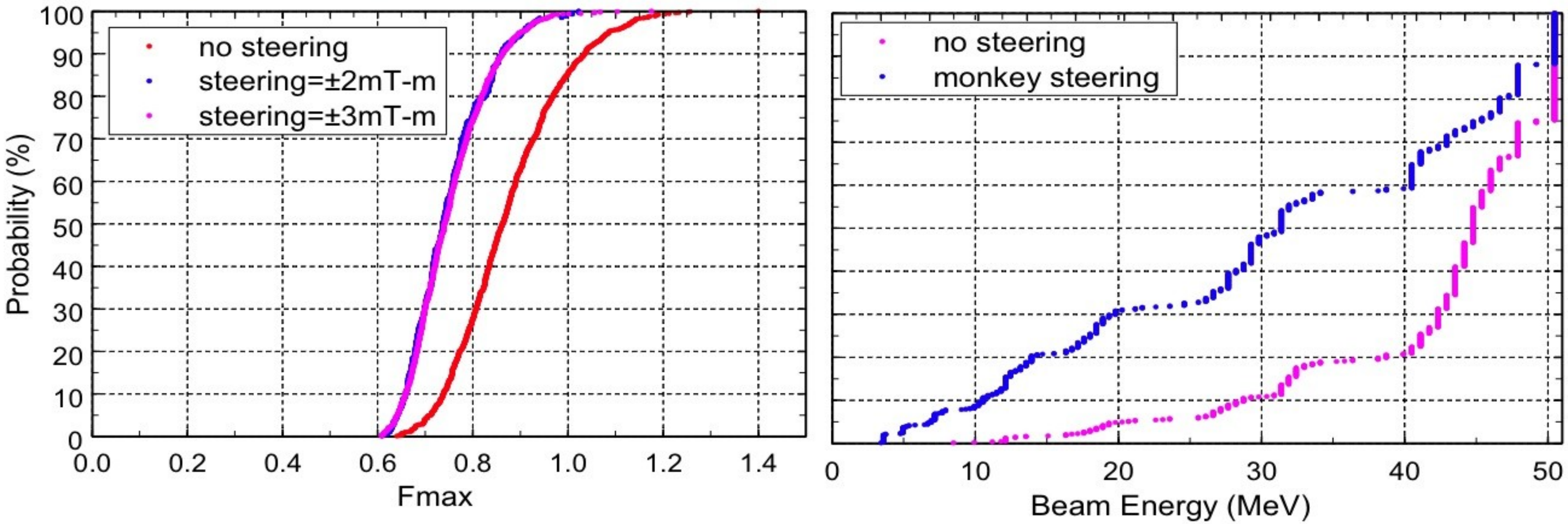


FIG. 7. (Color) Longitudinal acceptance measured at the second SCL cavity with the BCM at the exit of the SCL.

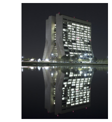
Front end: Stovall et al view

Eg 0.1 mm DTL misalignments matter

Error Studies Can Predict Expected Beam Loss Pattern



- With 50% probability an unsteering beam will clear the bore by 1.5 mm
- With 15% probability it will intercept the bore somewhere
- With 80% probability the loss will occur above 40 MeV
- With steering the beam will just touch the bore somewhere and
  - the expected beam loss is expected to be linear with energy
- An FDFD lattice is more sensitive to misalignments



Integrate multiple perspectives

"Single particle interacts with core" dominates the dynamics?

- Fast simulations can aid design ....

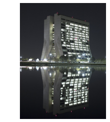
Integrate:

- Front end halo generation
- Warm-to-cold transition (& design opportunities)
- SC linac halo losses (longitudinal → transverse)

Can LLRF be incorporated?

- Feed-forward is crucial in lowering SNS losses
- Connect ESS, L4, and SPL activities?
- Does warm-to-cold allow separable design problems?

Conclusions



ESSS & ESSB have become ESS, sited in Lund, Sweden

With 13 member states (and counting)

First neutrons for 2018, with full design specs in 2023

Maximize synergies with other similar projects

Cost and time gains

Trained people are in short supply

Build on latest SC RF R&D

Require high reliability & low losses

Very challenging task… our job & our joy!