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A Conceptual Layout of the SC Linac for the ESS-Bilbao Accelerator

International Meeting on Fundamental Physics

Benasque, Feb. 13 2009

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Outline

- A Brief Account of the ESS Accel. Concept
- Pending issues with the ESS Baseline
- Schematics for the ESS-B Accelerator Designs
- ESS-B R&D Activities
- Wrap up & Conclusion

The European Spallation Source saga :A prom along a long, winding path

- Late 80´s - Early 90´s : Setting up of a study group at EU headquarters (Brussels DG XII) to envisage how to maintain european leadership in neutron scattering (i.e. Post I.L.L. Scenario)

- 1996 - First complete design spec finished. ESS Central project team moved to KFZ Juelich,

- 2002-2003 - Revised accelerator spec., mostly as a result of ISIS -CEA collaboration. KFZ-J to play the host role for the installation. Mid-2003, Central Project Team disbanded after a poor review by the Deutche Wissenschaftrat,

- 2003-2004 - A team of survivors (ESS-Initiative) settles at the Institut Laue Langevin (Grenoble) to keep the project minimally alive,

- 2008 - ESS included within the list of EU Large Infrastructures. Three countries remain interested in hosting the installation : Hungary (Debrecen), Spain (Bilbao) and Sweden (Lund). The three bidding places have been recently scrutinized by an international panel,

- 2008 - … ESS will not be financed thru EU channels but rather, as a result of multilateral agreements.

Feel the four fundamental interactions

- Massive Particle (1.67 x 10^{-27} kg) composed by quarks (u d d), stabilized by the strong interaction,

- Relatively short lifetime (885.8 s vs >10^{30} years for p). Decays into p +e^-+ν_e (beta decay, a manifestation of the weak interaction,)

- Without measurable electric charge but probably having a non-zero electriv dipole moment (< 1 x 10^{-26} e-cm)

- Has a pretty respetable magnetic dipole moment 1.913 μ_N ,

- Feel the gravitational fields (gravitational interaction)

Effects of Earth´s rotation on the phase of the de Broglie wave

PHYSICAL REVIEW A VOLUME 21, NUMBER 5 MAY 1980

Gravity and inertia in quantum mechanics

J.-L. Staudenmann and S. A. Werner
Physics Department and Research Reactor Facility, University of Missouri-Columbia, Columbia, Missouri 65211

R. Colella and A. W. Overhauser
Physics Department, Purdue University, West Lafayette, Indiana 47907
(Received 11 September 1979)

The experiments described in this paper probe the simultaneous effects of gravity, inertia, and quantum mechanics on the motion of the neutron. Using a neutron interferometer of the type developed by Bonse and Hart for x rays, we have observed quantum-mechanical interference phenomena induced by the gravitational field of the Earth and by the Earth's rotation relative to the fixed stars. The importance of these experiments with regard to the role of the principle of equivalence in quantum mechanics is discussed.

All verifications of the equivalence principle, prior to our experiment, have been in the classical domain. The experimental results did not depend on Planck's constant. For the experiments described in this paper, the number of interference fringes observed for a given rotation of the interferometer depends on the numerical value of Planck's constant, and therefore represent a test of the principle of equivalence in the *quantum limit*.

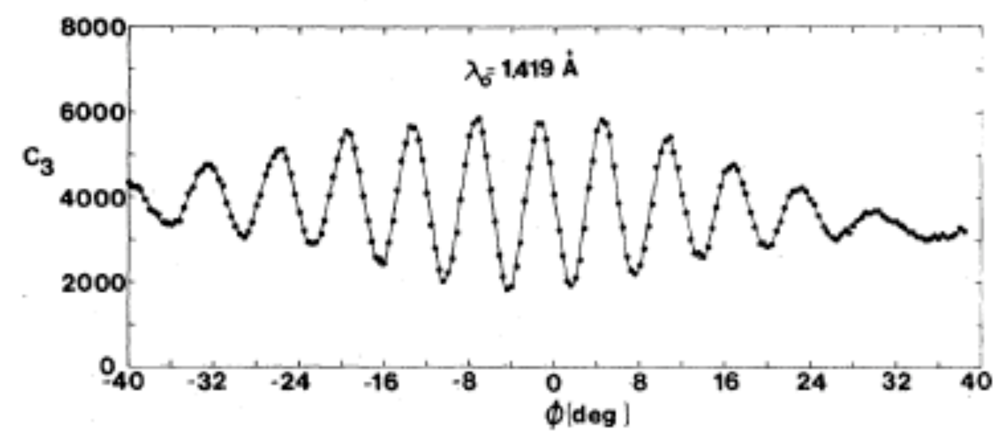

FIG. 12. Gravitationally induced quantum interference experiment at $\lambda_0 = 1.419$ Å. The counting time was about 7 min per point.

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Nature 415, 297-299 (17 January 2002)

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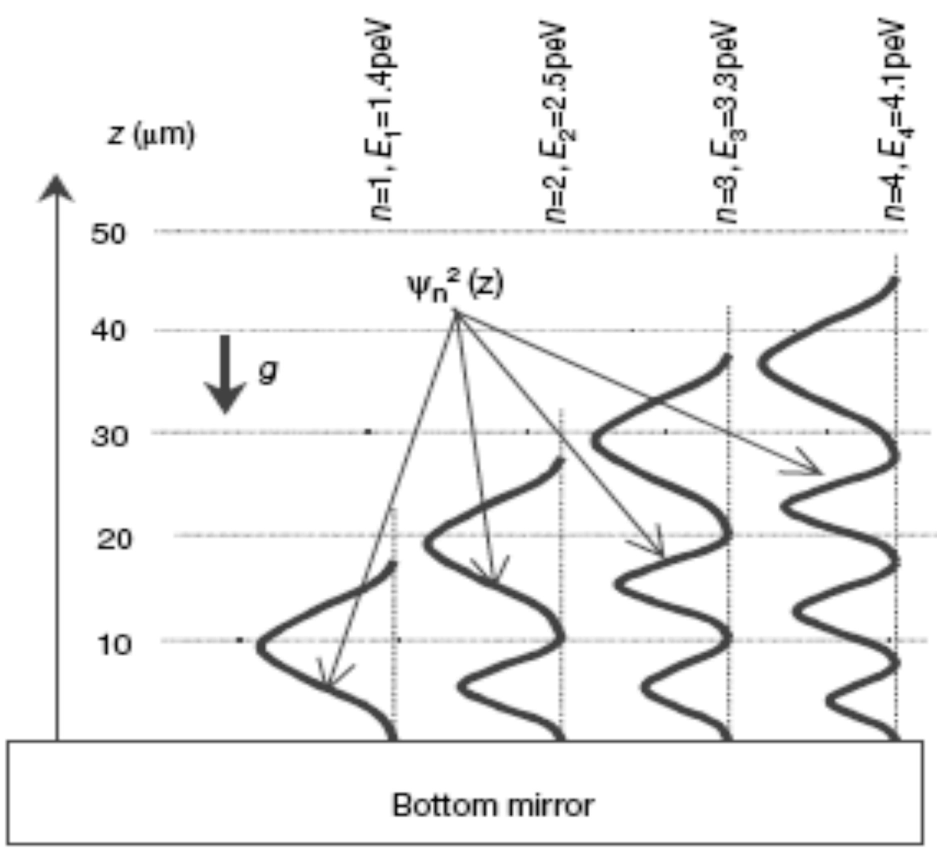

Figure 1 Wavefunctions of the quantum states of neutrons in the potential well formed by the Earth's gravitational field and the horizontal mirror. The probability of finding neutrons at height z, corresponding to the nth quantum state, is proportional to the square of the neutron wavefunction $\psi_n^2(z)$. The vertical axis z provides the length scale for this phenomenon. E_n is the energy of the nth quantum state.

Quantum states of neutrons in the Earth's gravitational field

Valery V. Nesvizhevsky*, Hans G. Börner*, Alexander K. Petukhov*, Hartmut Abele†, Stefan Baeßler†, Frank J. Rueß†, Thilo Stöferle†, Alexander Westphal†, Alexei M. Gagarski‡, Guennady A. Petrov‡ & Alexander V. Strelkov§

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§ *Joint Institute for Nuclear Research, Dubna, Moscow reg. R-141980, Russia*

- Effective temperature of neutrons is ~20 nK
- Background suppression is a factor of ~10^8-10^9
- Absolute horizontal leveling precision is ~10^-6 rad
- Parallelism of the bottom mirror and the absorber /scatterer is ~10^-6

Orders of magnitude for neutron energies used in CMS

Epithermal-> 2000 K, E = 172.4 meV, λ= 0.07 nm, v = 5743 m/s

10 eV

Thermal -> 300 K , E = 25.8 meV, λ= 0.18 nm, v = 2213 m/s

Cold -> 10 K, E = 0.82 meV, λ= 1.0 nm, v = 396 m/s

Ultracold -> 1.52 mK, E = 130 neV, λ= 79 nm, v = 5 m/s

Massive Production of Neutrons

Mthod	Fission	Electrons	Protons
Reaction	fission (n,n)	Bremstrahlung (γ,n)	spallation (p,n)
E_{in}	thermal	100 MeV	1 GeV
Efficiency	1 n/ ev.	0.05 n/ ev.	30 n/p
Produced Heat	180 MeV	2000 MeV	55 MeV

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ESS 2003 Update : Two alternative designs

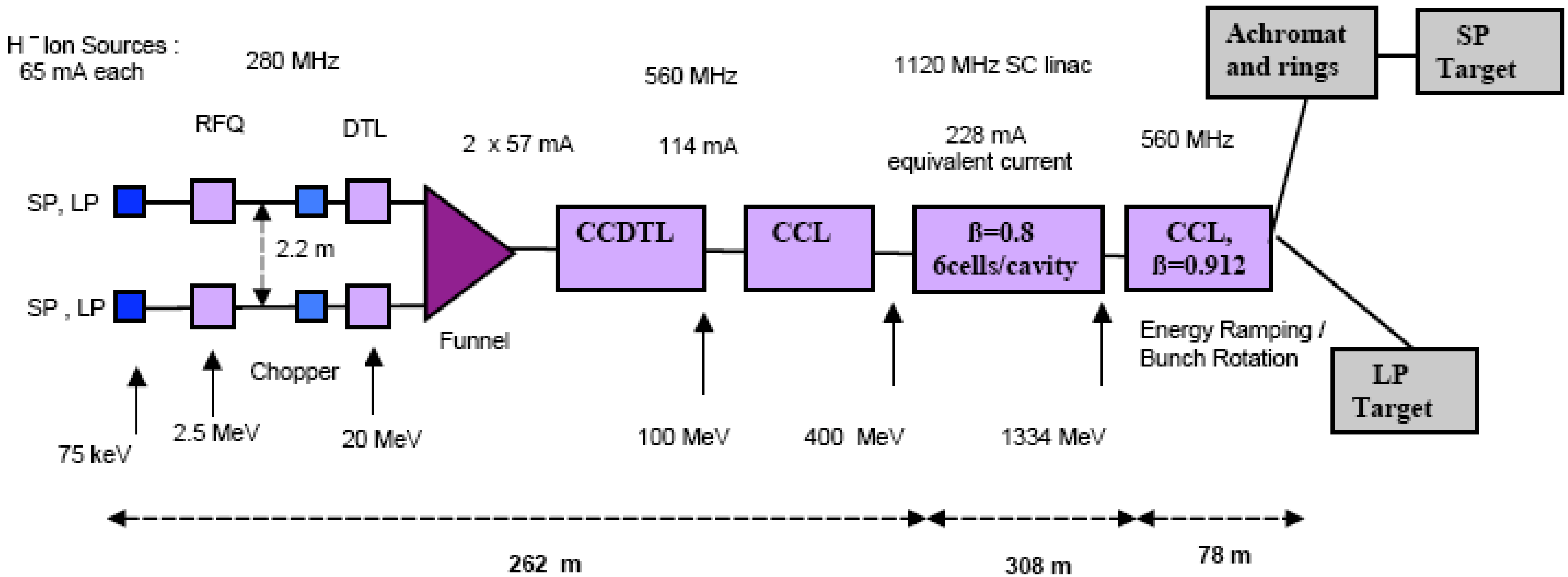


Figure 1.3.1: The ESS 1120 MHz Superconducting (SC) reference Linac

Parameter List for the dual Short & Long Pulse Machine

	SP	LP	
Beam Data			
PRF (pulses per second)	50	16.67	
Beam pulse length(ms)	2x0.48	2.0	
Beam duty factor	4.8%	3.3%	
Non-chopped beam current (mA)	114	114	
Chopping factor	70%	70%	100%
Final energy (MeV)	1334	1334	
Peak beam power (MW)	107	107	152
Mean beam power (MW)	5.1	3.5	5.1
Pulse gaps, ring separation (ms)	0.1		
280/560 MHz NC-Linac			
Energy range (MeV)	400		
NC linac length (m)	262		
Peak RF power (nominal)(MW)	64	78 (100%)	
RF pulse: length (msec) / duty cycle (d.c.)	1.4/7.0%	2.3/3.83%	
Wall plug RF power (MW) (30 % RF control included)	12	8	
1120 MHz SC-Linac			
Energy range (MeV)	400 –1334		
SC linac length (m)	308		
Accel. gradient in SC cells (MV/m)	10.2		
Peak RF power (nominal) (MW)	75	107 (100 %)	
RF pulse: length (ms) / d.c.	1.4/7.0%	2.3/3.83%	
Wall plug RF power (MW) (30 / 40 % RF control included)	15 (40 %)	11 (30 %)	
AC Cryo power (MW)	2.4	1.6	

Short and long pulses interleaved

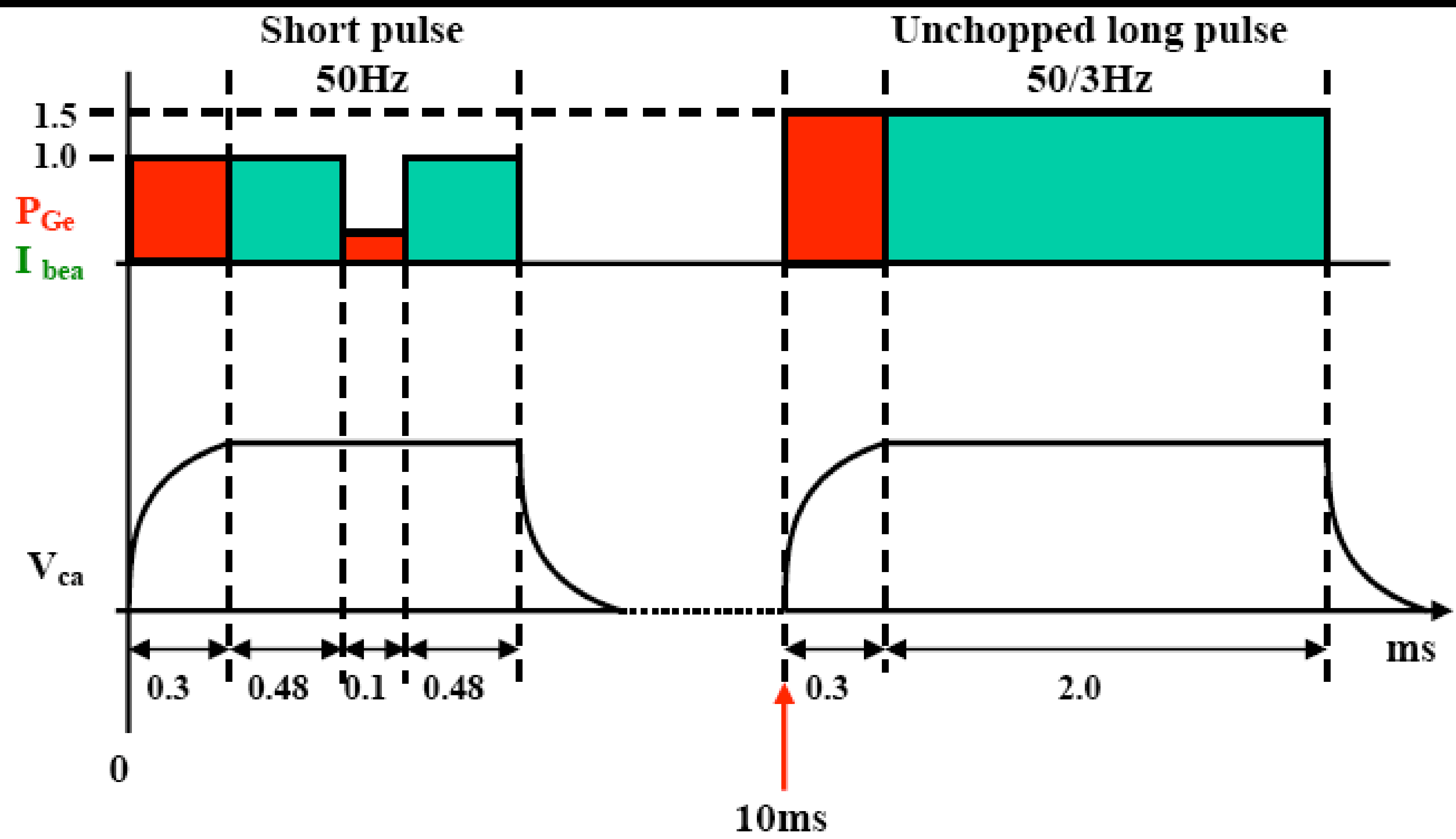
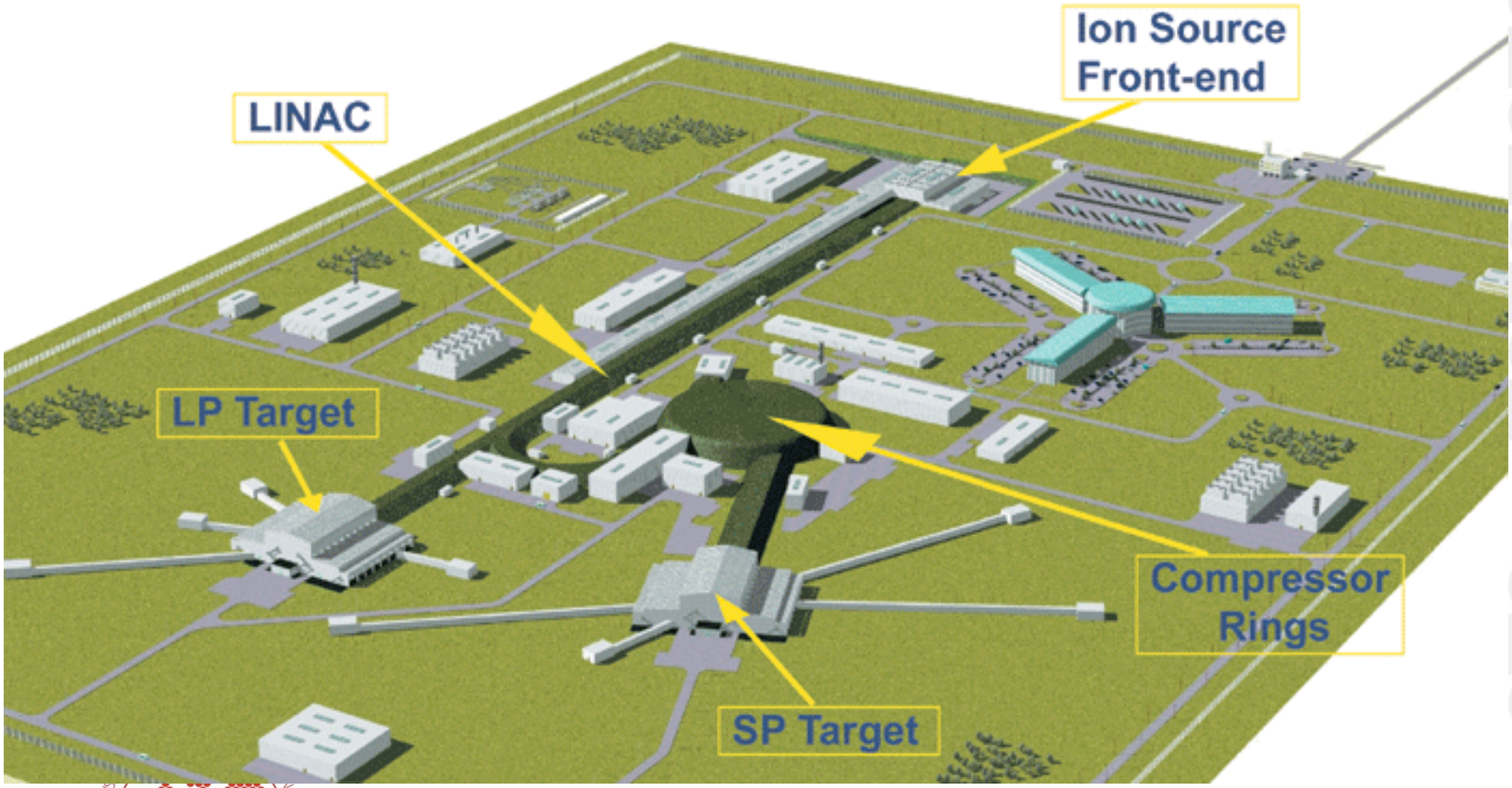


Figure 1.3.2: Pulse sequence on ESS linac, V_{ca}= Cavity voltage, I_{bea} = beam current relative to a chopped beam, P_{Ge} power from the RF generator for the SC cavities. Between the two ring pulses, the RF generator power has to be reduces to about 25 % in order to keep the accelerating voltage unchanged. Not shown are the two other chopped pulses given to the SP target.


Ion Source
Front-end
LINAC
LP Target
SP Target
Compressor
Rings

ESS 2008 Baseline as conceived by ESS-S and ESS-H

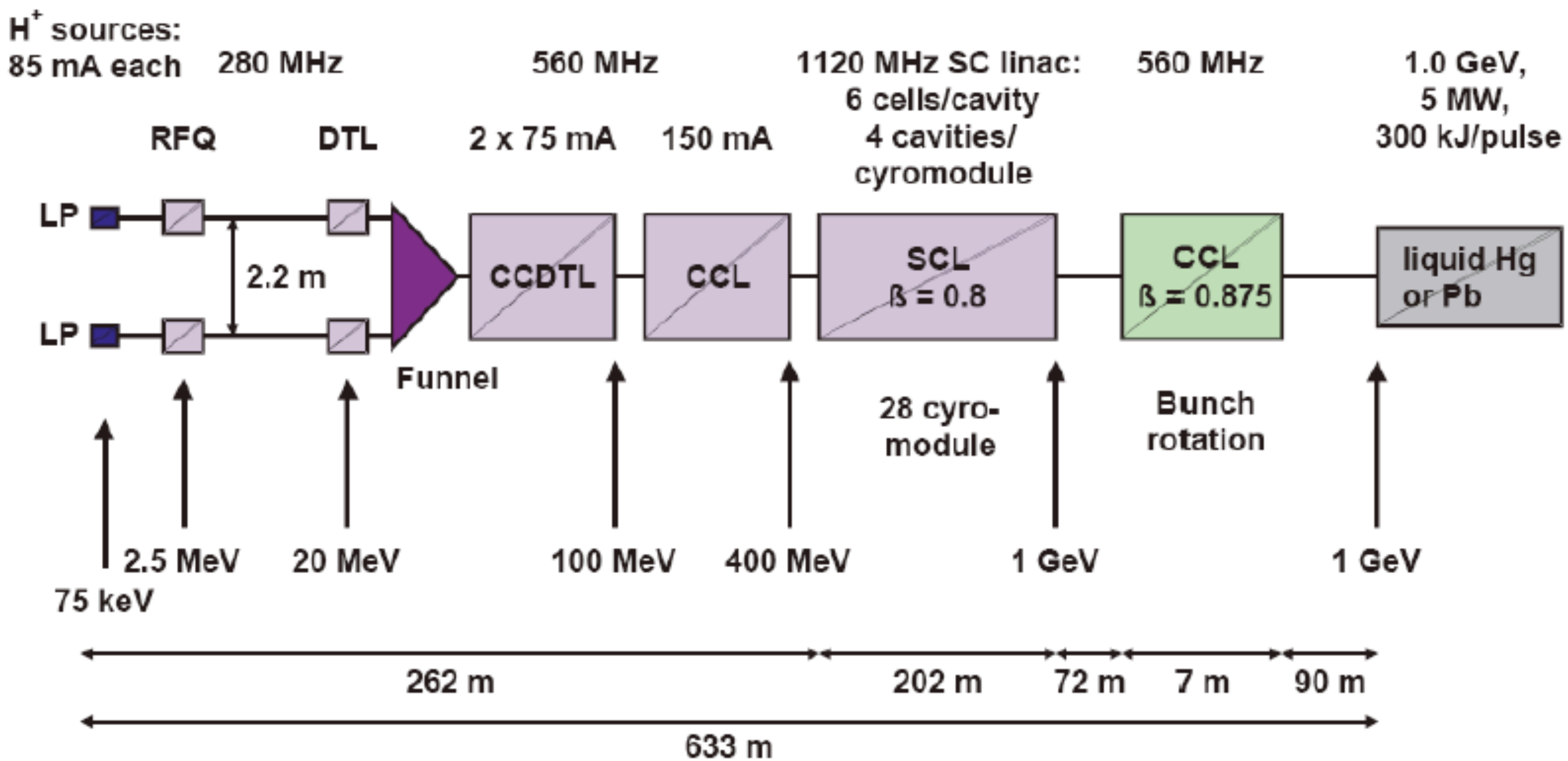


Figure 8: ESS H+ SC Linac, 4 % RF duty, serving only LP target

Schematics for the Funnel Section : Easy to draw on paper

Proceedings of EPAC 2002, Paris, France

ESS FUNNEL DEVICE INVESTIGATION ACCELERATOR

Y.Senichev*, W.Braeutigam, R.Maier, FZJ, Jülich, Germany, A.Zherebtsov**, A.Barsukov, O.Belyaev, Yu.Budanov,I.Grushichev, V.Stepanov, V.Teplyakov, I.Zvonarev, IHEP, Russia

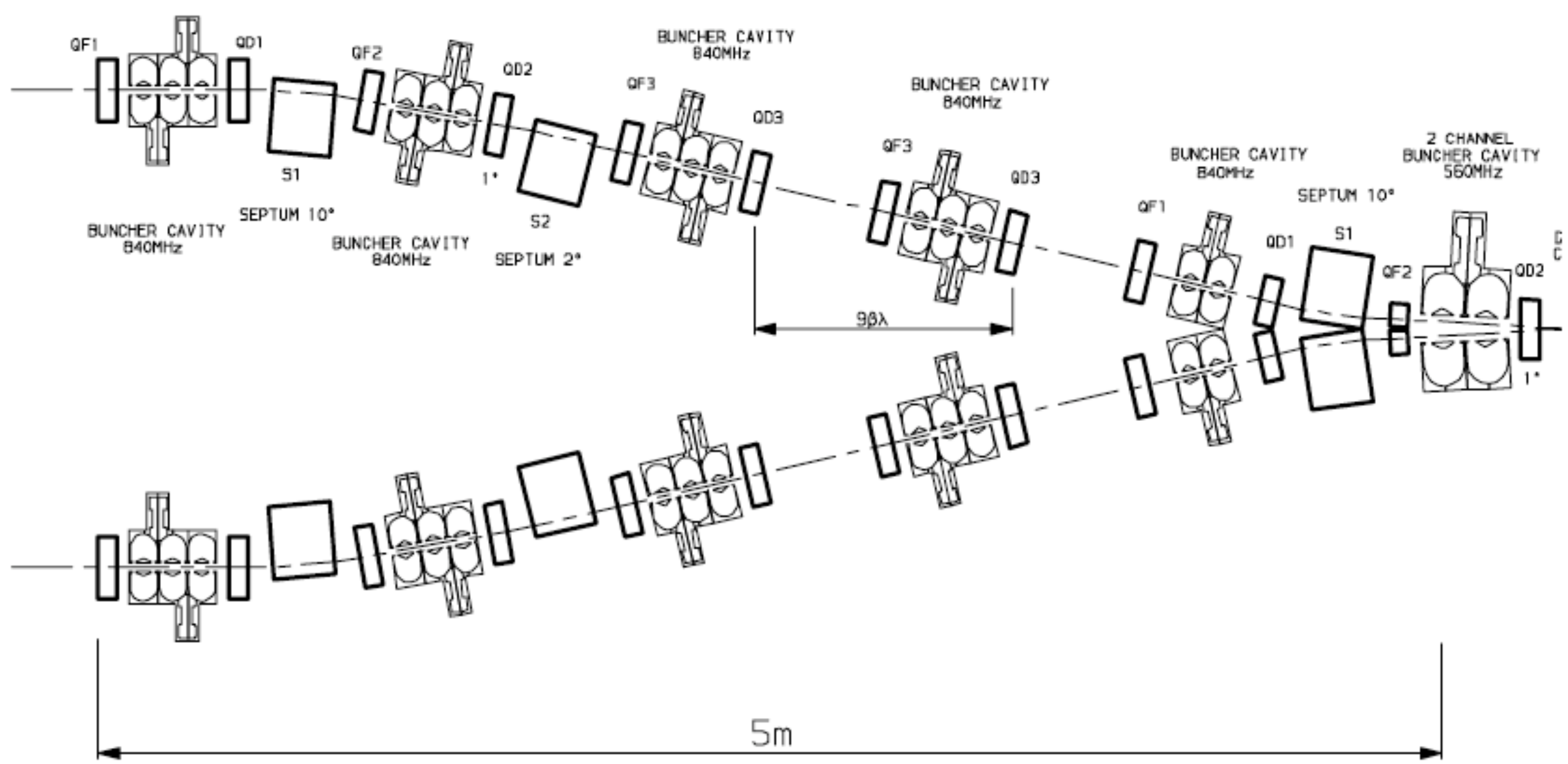


Figure 1.3-13: Schematic layout of the 280 to 560 MHz Funnel

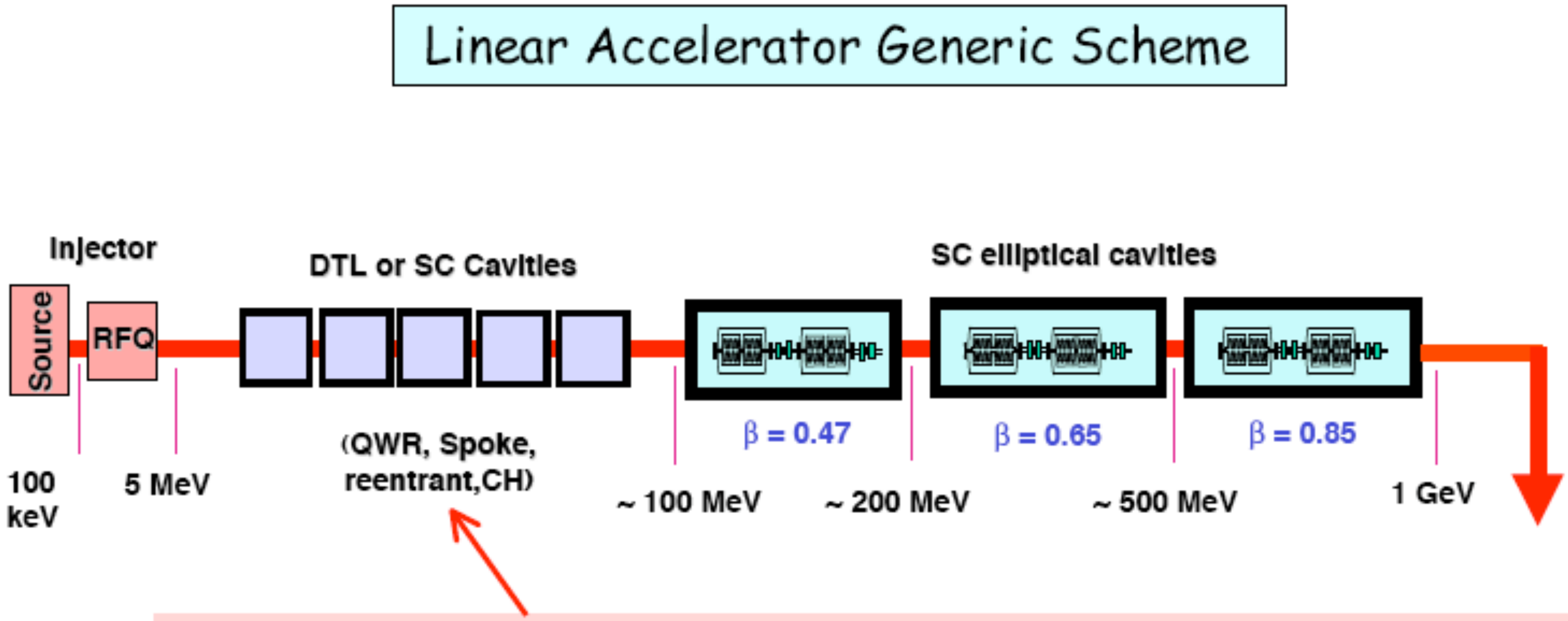
Matters arising the ESS 2003/2008 Baseline :

- It has been taken as a basis for construction and operation costs,
- Has been used to determine the site requirements,
- Sets the spec for energy, power and time structure,
- A number of pending issues requiring a significant R&D effort still remain, particularly those concerning the front end,
- Dual mode, short/long pulses operation needs to be proven feasible,
- SC technology is now a proven thing. This may have implications on whether or not a long, warm LINAC is still needed.

A revision of the accelerator design is highly advisable

- The 2008 ESS baseline has potential show-stoppers: i.e. the funnel section may be far more difficult to build than previously thought, can we do without ?
- SC cavities are nowadays the choice for accelerating devices for energies well below the 400 MeV mark given in the ESS baseline,
- The current 2008 baseline considers three frequency jumps which may perhaps be reduced to two (cheaper and safer),
- Accelerating gradients are limited to 10.2 MV/m (far too modest),
- As it stands, synergies with other existing projects are difficult to envisage.

Can we do better than ESS current baseline?



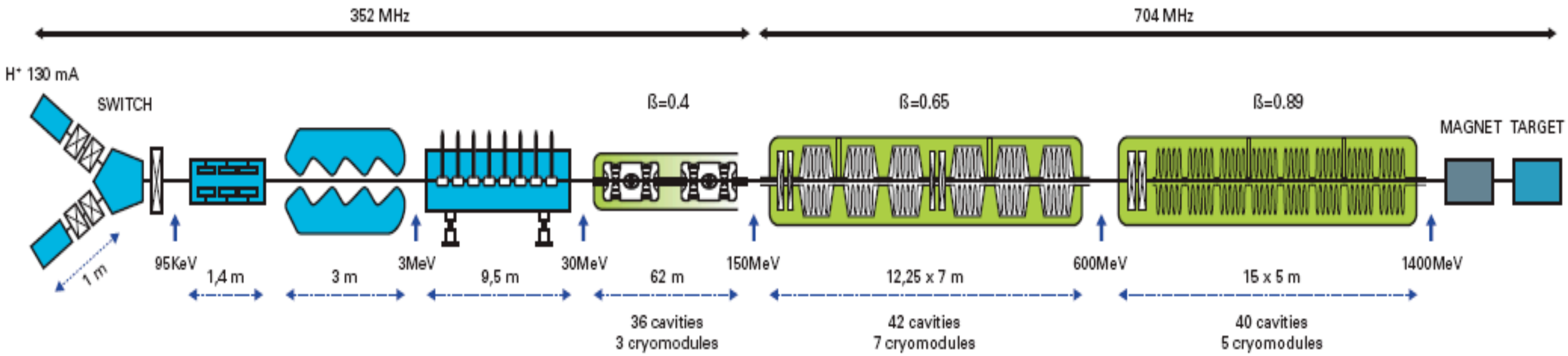
Interest of Spoke Resonators :

- Large beam aperture
- Mechanical stability
- Negligible steering effects
- Modularity : Independent RF powering and control

A few constraints to the design,

- use existing acceleration devices whenever possible
- minimize the number of sections/lattice transitions
- minimize the number of bunch frequencies
- maximize accelerating fields while keeping peak surface fieldsbelow safe values (70 mT for B_{peak} and gradients below 30 MV/m)
- minimize the Linac length (cost of present-day linacs : 1 M€/m)
- keep beam losses below 1 W/m,
- select those operating frequencies to match those: *a) used by the low-energy front-ends within current-day projects where synergies are expected; b) employed by cavities and couplers already developed; c) provided by klystrons commercially available and a smaller number of cavities to be employed,*
- choose those accelerating structures which show more potential reliability-wise (highly modular with some degree of redundancy)

A first estimate for the dimensions of the ESS-B linac



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Some numerical estimates

Table 3: RFQ

Parameter	Value	Comment
Structure	LInac4-type, 4-vane	
Length	3 m	
Input Energy	95 keV	
Cells	300	
Output Energy	3 MeV	
RF Frequency	352.2 MHz	
Input Current	110 mA	Subject to optimization
Output Current	105 mA	Subject to optimization
Vane voltage	90- 120 kV	"" ""
Vane aperture	0.4 - 0.2 cm	
Synchronous Phase	-90 - 50	"" ""
Modulation Factor	1 - 1.7	
Max Surf.Field	2 Kilpatrick	"" ""
Klystrons	1	"" ""
RF Beam Power (Total)	850 kW	" "

Table 4: DTL

Parameter	Tank1	Tank2
Length	3.5 m	6 m
Gradient (MV/m)	3.5	3.5
Output Energy (MeV)	13 MeV	30 MeV
Radius (cm)	1	1
Diameter (m)	0.52	0.52
Diameter DT (cm)	9	9
PMQ length(cm)	4.5	8
Peak RF Power (MW)	0.8	1.7
Max.Surf.Field (Kilp.)	1.8	1.6
Klystrons	1	2

…for the SC section

Table 5: Spoke parameters

Parameter	
Type	Triple Spoke
Gradient (MV/m)	10
Input Energy (MeV)	30 MeV
Output Energy (MeV)	150 MeV
Effective length (cm)	8.5
Length (cm)	80
Beam aperture (cm)	4
N. cavities	36
Lattice	FODO
N. cavities/Foc.Lat.	2
N.cryomodules	3
E_{peak}/E_{acc}	≤ 4
B_{peak}/E_{acc}	≤ 10
B_{max} (mT)	80
E gain per meter (MeV/m)	1.9
Beam RF power / cavity (kW)	3 - 20
Operation temperature	2 K

Table 6: Low β elliptical

Parameter	
Type	Elliptical
Geometric β	0.65
Gradient (MV/m)	19
Input Energy (MeV)	150 MeV
Output Energy (MeV)	600 MeV
Length per cryomod (m)	12.2
Cavity effective length (cm)	69
Beam aperture (cm)	8.5
N. cavities	42
Lattice	FDO
Period length (cm)	60
Periods/module	2
N.cryomodules	7
E gain per meter (MeV/m)	5.8
Max beam RF power / cavity (kW)	1000
Cavities/klystron	8
Operation temperature	2 K

Some remarks on the proposed design

- Technology is now mature to push the accelerator superconducting section down to a few tens of MeV (EURISOL – 1.5 MeV/u, HINS/Project X – 10 MeV, EUROTRANS – 20 MeV)

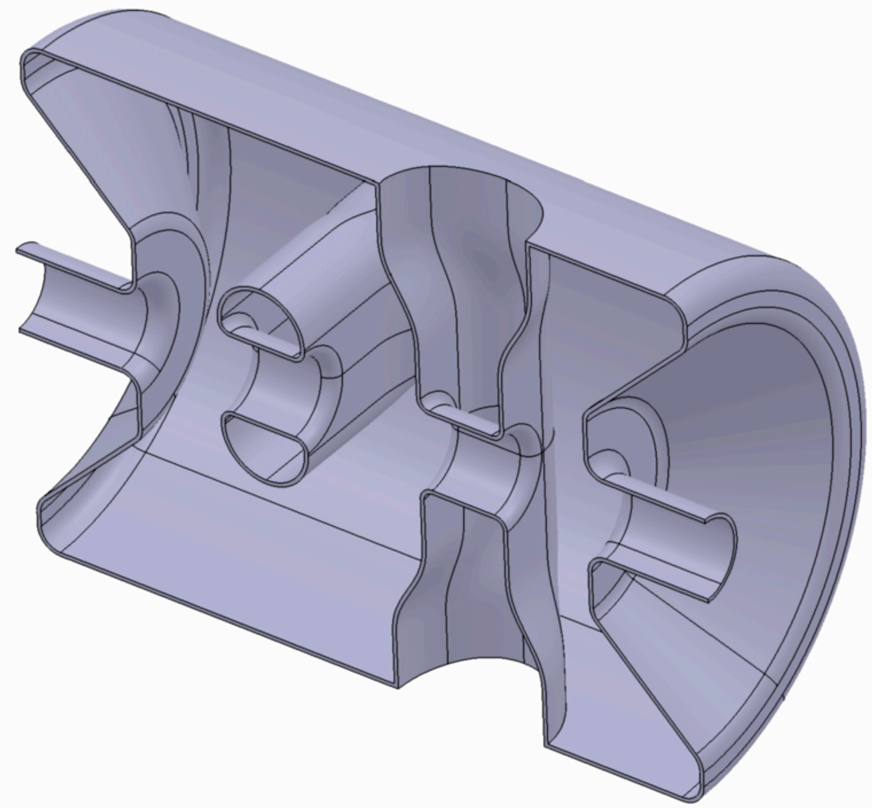
- Super-conducting cavities show additional advantages such as : a) Beam apertures of a few cm , b) Mechanically more stable than warm components; c) Allow fast dynamic compensation of tuning failures leading to far enhanced reliable operation; d) enable a far more efficient use of the RF power,

- SC LINACs are , by force, significantly shorter in length! Expenditure in cryogenics plants will most certainly be compensated by savings in rising electricity costs,

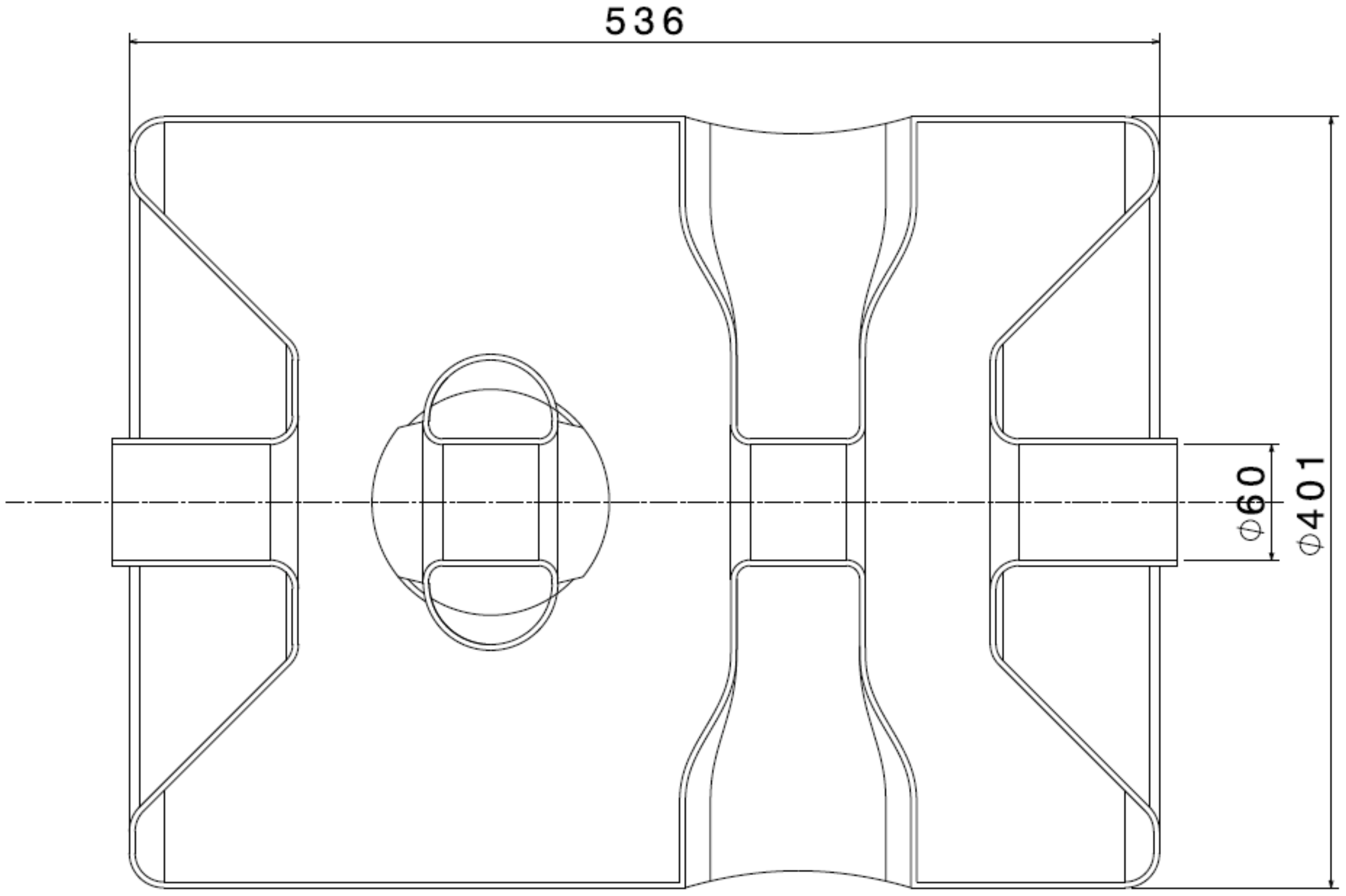
- There are pending feasibily issues concerning the liquid metal target. Rotating solid-metal considered as a safe, backdrop option.

Which spoke cavities do we want ?

Energy range –	30 –MeV -- 150 MeV
Beam Current –	100 mA
Rep. Rate –	30 Hz
Pulse Length–	< 1 ms
Duty Factor–	3.%
Frequency –	352.2 MHz
Transv. Emittance (input)–	0.2π mm mr (rms norm.
Long. Emittance (input)–	0.2π deg MeV
Beam aperture –	6 cm
Eacc –	8-9 MV/m (optimally)
Q –	7 x 10^8
β –	0.35
Acceleration	1.8 MeV/m
Peak.surf.mag. field.	< 90 mT
Oper.Temp.	4 K



ESS-B Double spoke



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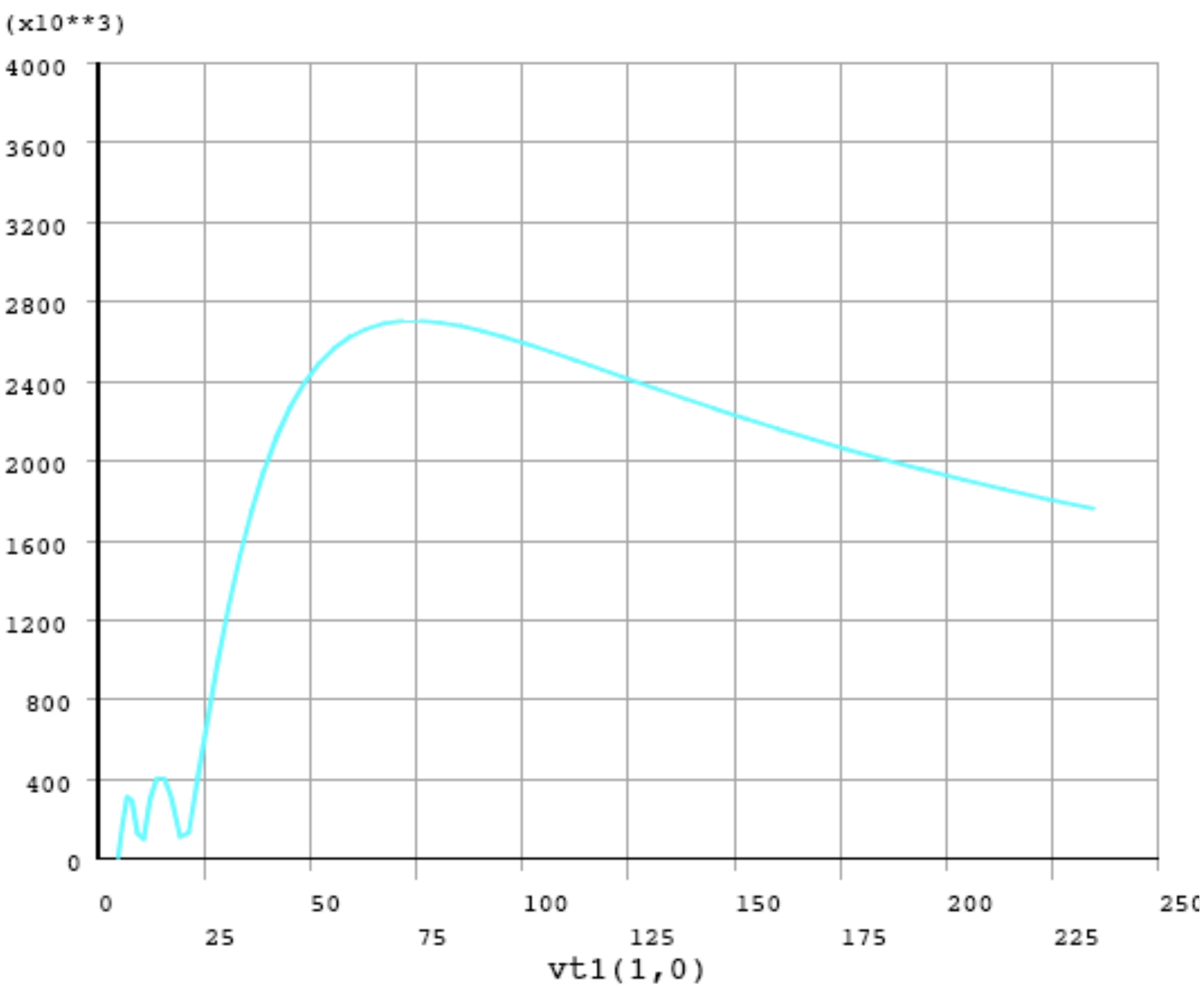
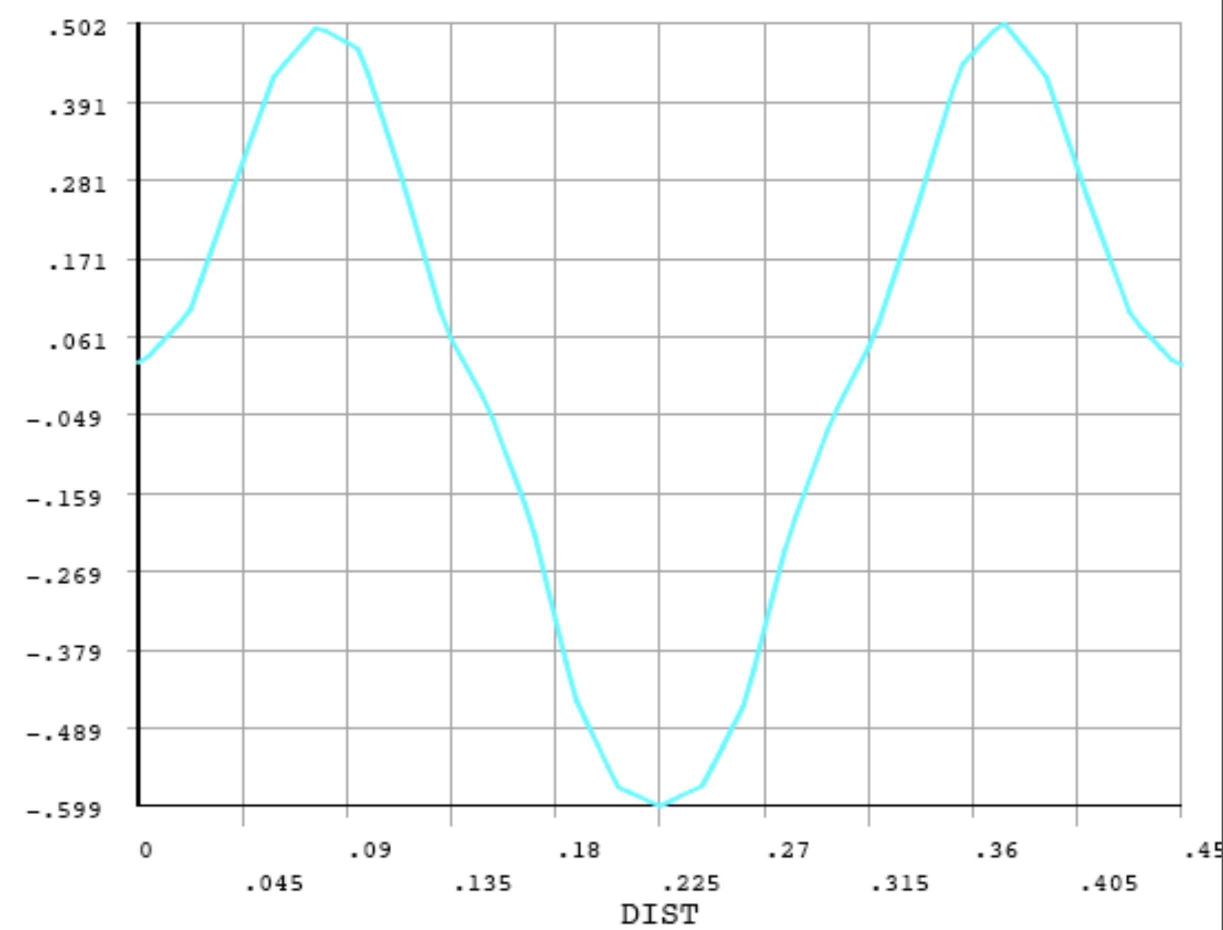
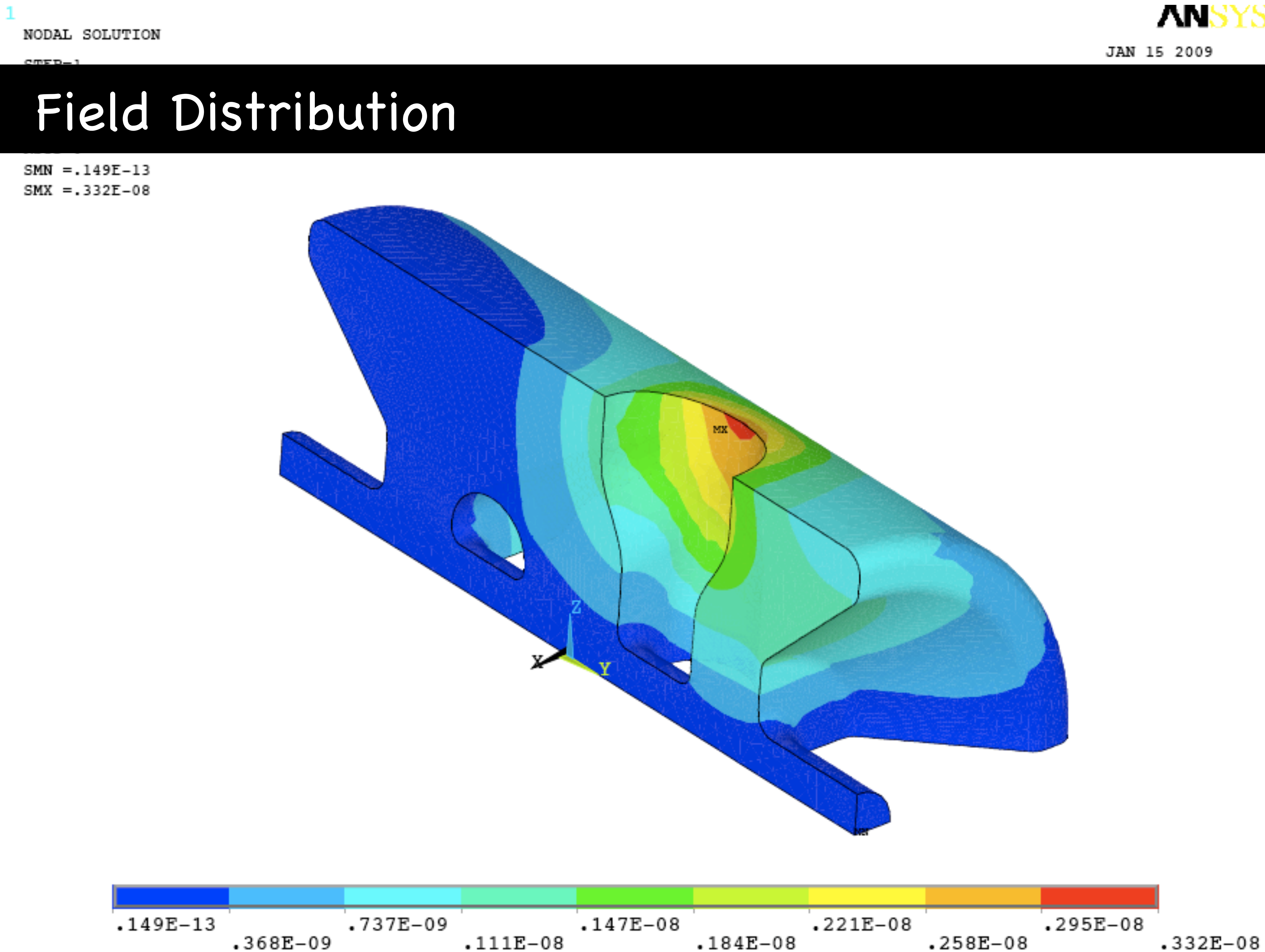
Field Distribution and TTF

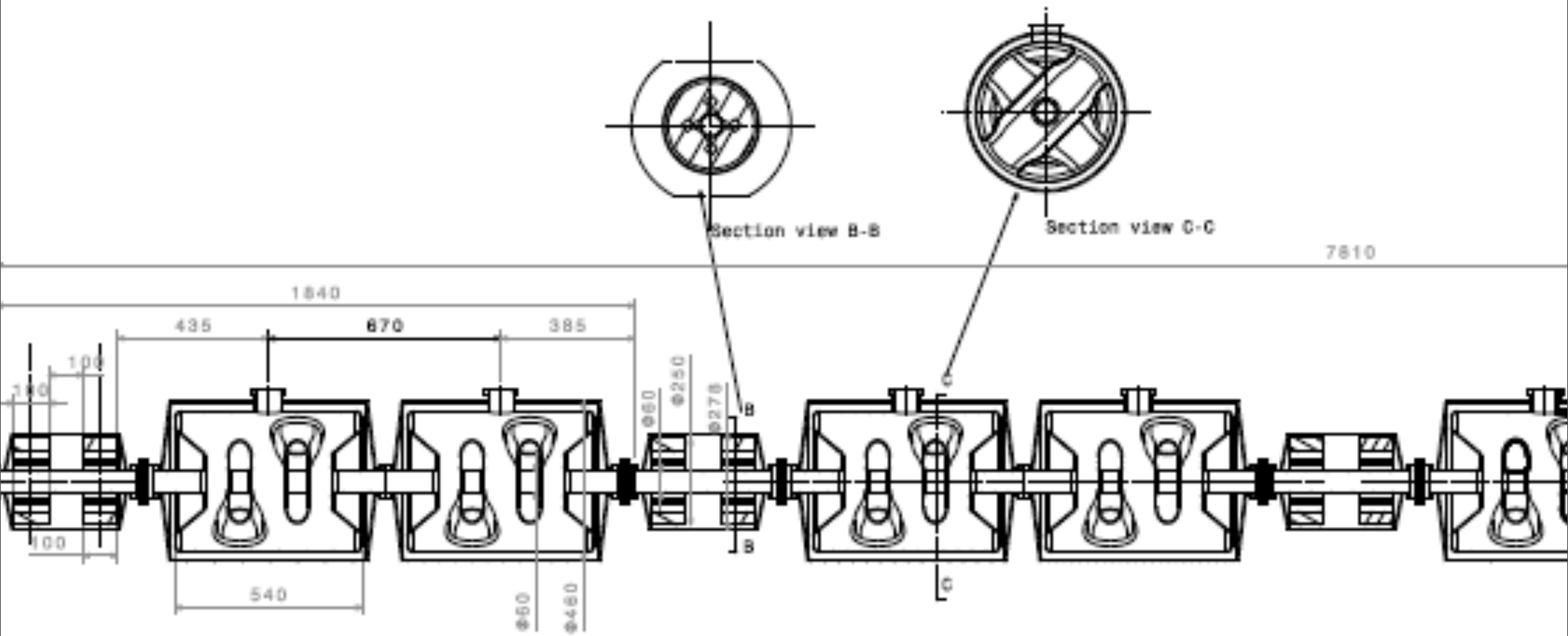




Field Distribution



A section of the ESS-B double spokes linac



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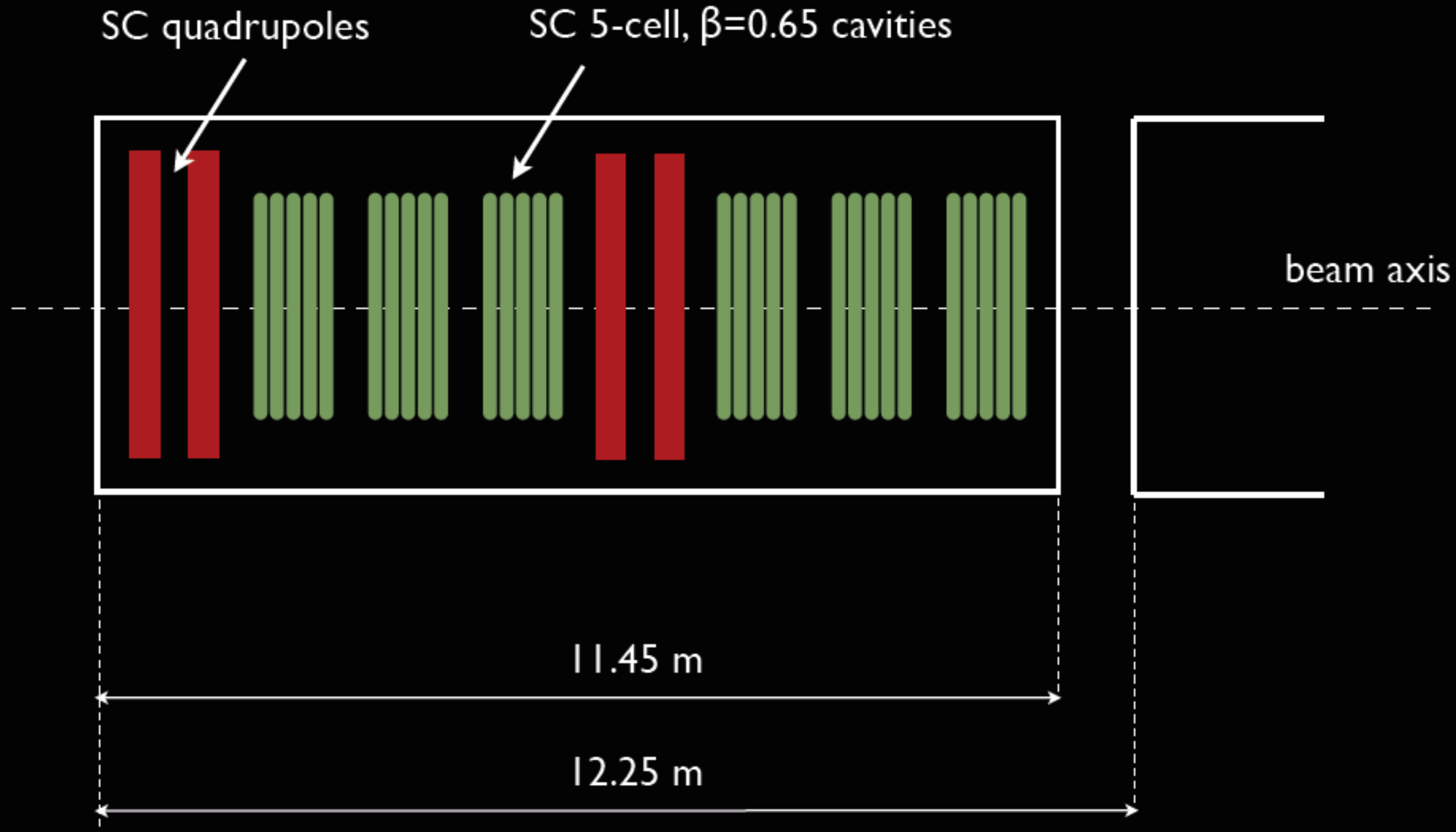
Elliptical cavs. adapted from SCL

doublet focusing, 2 periods per module



Beam dynamics incl. error studies and steering: R. Duperrier, D. Uriot, CEA

Already existing beta= 0.65 cavs.

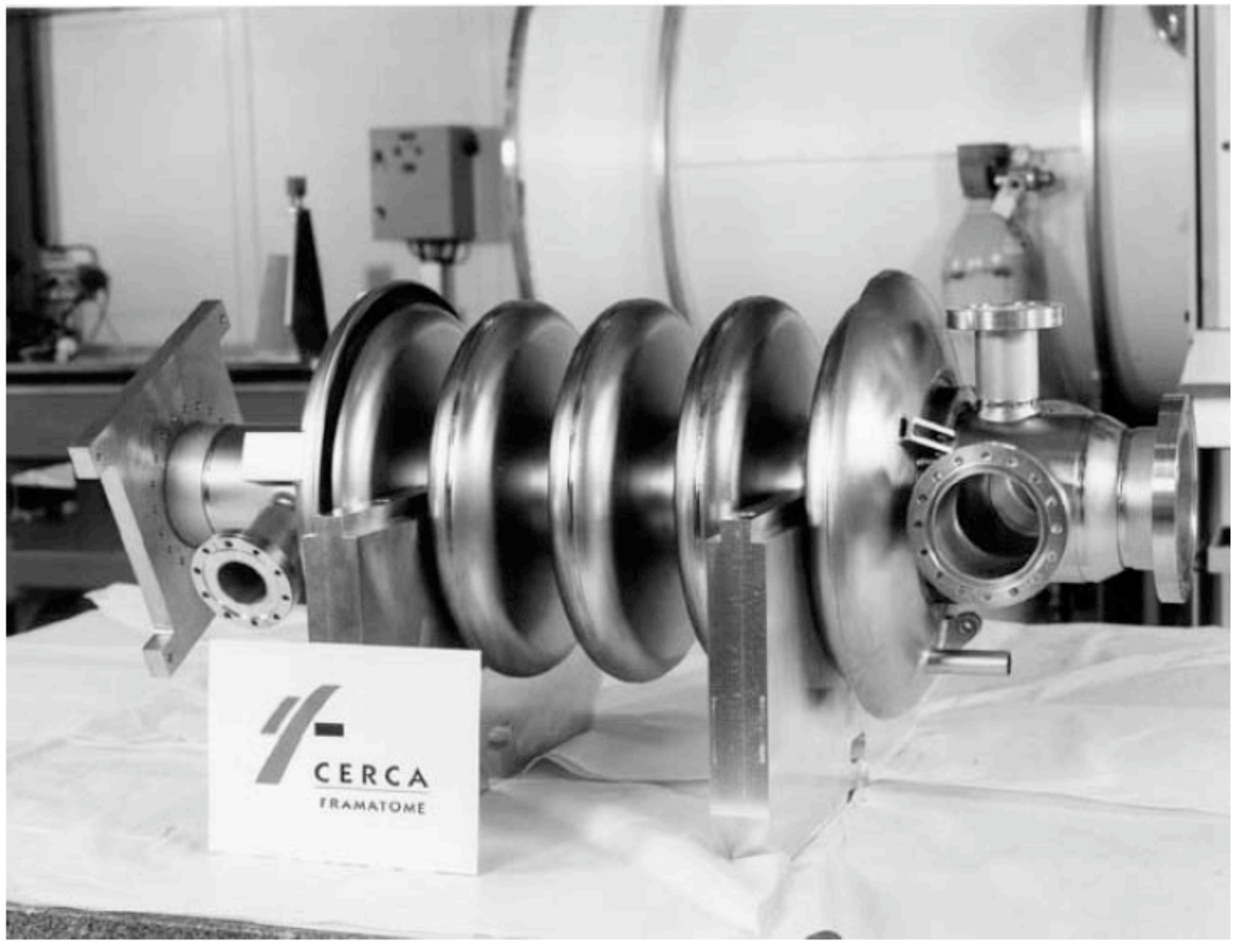


Figure 2.18. Test results from CEA-Saclay/IPN-Orasy beta = 0.65 elliptical cavities

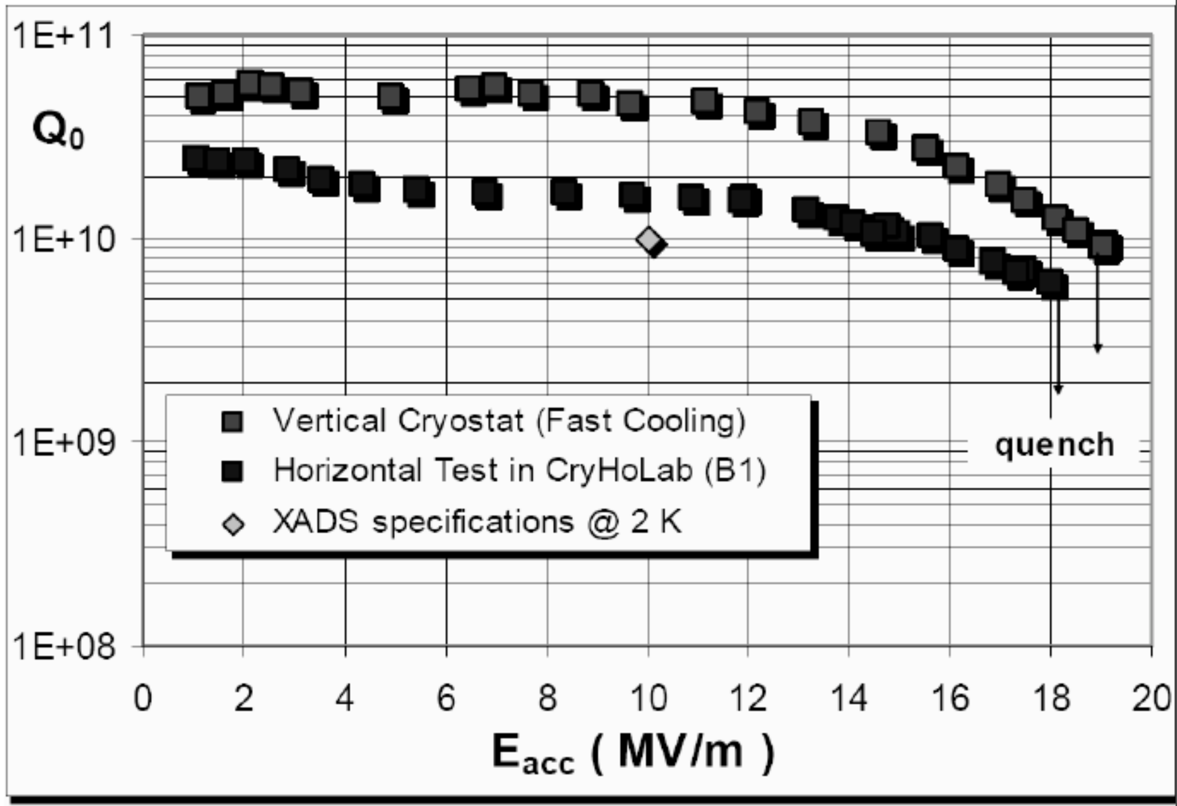
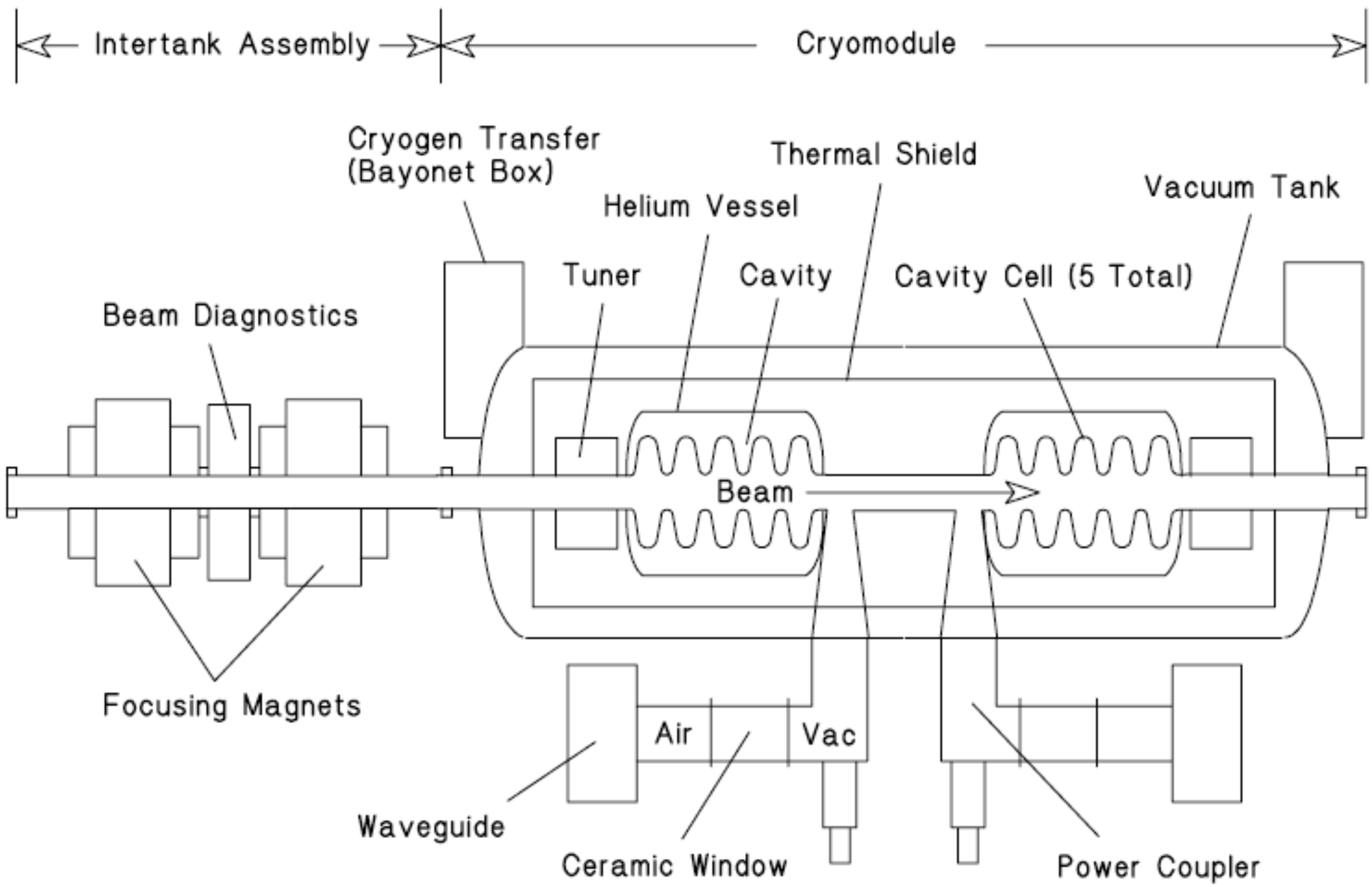


Figure 2.19. Sketch layout of APT beta = 0.64 cryomodule and quadrupole doublet in intervening warm space



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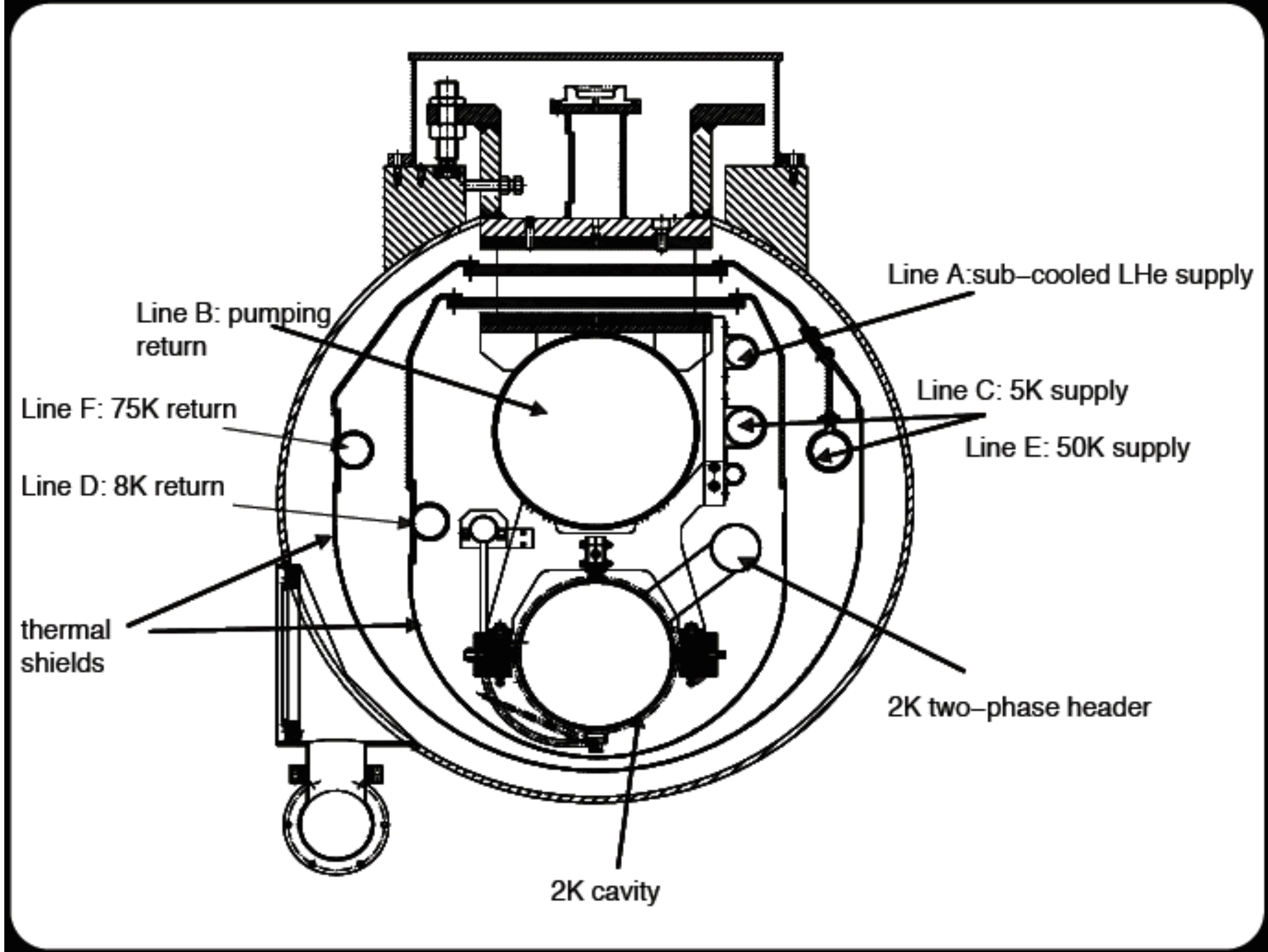
Cryomodules : Start from ILC/TESLA



- long modules with a low number of cold/warm transitions and low static losses,
- cold quadrupoles,
- high packing factor,
- requires high reliability of all components and several years of R&D!

The ESS-B Accelerator Concept,

- A single proton source may do the job, SILHI has reached 140 mA. Operation with the switch magnet enables RF preconditioning of a new source providing enhanced reliable operation
- A RFQ and DTL very close in design to that of Linac4 suffices to reach some 40 MeV,
- SC cavities (spokes) are proven to provide acceleration up to 150 MeV,
- Two sets of elliptical SC cavities required to reach 1400 MeV,
- A considerable degree of built-in redundancy is planned to allow tuning by means of dynamic compensation schemes
- Operating frequencies to match those of Linac4,

R&D issues to address

- Need to attenuate higher-order-modes. HOMs drive longitudinal and transverse coupled bunch instabilities, which need to be controlled using active feedback systems,
- The deleterious effects of wake fields at the high beam currents we are aiming at need to be quantified in terms of the emittance growth,
- Need to assess the best method to deal with frequency jump (Duperrier PRST-AB 10, 084201 2007)
- A whole new set of diagnostic tools needs to be thought.

Power Couplers

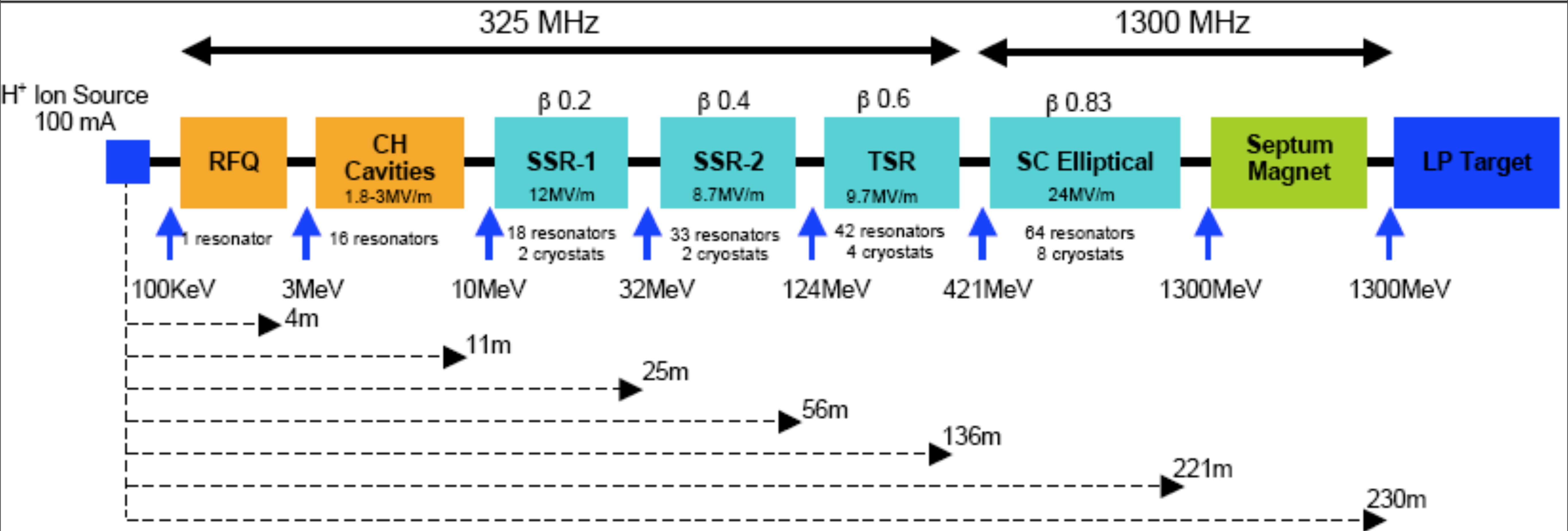
OVERVIEW OF INPUT POWER COUPLER DEVELOPMENTS, PULSED AND CW*

S. Belomestnykh#, CLASSE, Cornell University, Ithaca, NY 14853, U.S.A.

Table 2: Pulsed input couplers for superconducting cavities.

Facility	Frequency	Coupler type	RF window	Q_{ext}	Max. power	Pulse length & rep. rate
SNS	805 MHz	Coax fixed	Disk, coax	7×10^5	Test: 2 MW Oper: 550 kW	1.3 msec, 60 Hz 1.3 msec, 60 Hz
J-PARC	972 MHz	Coax fixed	Disk, coax	5×10^5	Test: 2.2 MW 370 kW	0.6 msec, 25 Hz 3.0 msec, 25 Hz
FLASH	1300 MHz	Coax variable (FNAL)	Conical (cold), WG planar (warm)	1×10^6 to 1×10^7	Test: 250 kW Oper: 250 kW	1.3 msec, 10 Hz 1.3 msec, 10 Hz
FLASH	1300 MHz	Coax variable (TTF-II)	Cylindrical (cold), WG planar (warm)	1×10^6 to 1×10^7	Test: 1 MW Oper: 250 kW	1.3 msec, 10 Hz 1.3 msec, 10 Hz
FLASH / XFEL/ ILC	1300 MHz	Coax variable (TTF-III)	Cylindrical (cold and warm)	1×10^6 to 1×10^7	Test: 1.5 MW 1 MW Oper: 250 kW	1.3 msec, 2 Hz 1.3 msec, 10 Hz 1.3 msec, 10 Hz
KEK STF	1300 MHz	Coax fixed (baseline ILC cavity)	Disks, coax (cold and warm)	2×10^6	Test: 1.9 MW 1 MW	10 µsec, 5 Hz 1.5 msec, 5 Hz
KEK STF	1300 MHz	Coax fixed (low loss ILC cavity)	Disk (cold), cylindrical (warm)	2×10^6	Test: 2 MW 1 MW	1.5 msec, 3 Hz 1.5 msec, 5 Hz

A second, futuristic alternative



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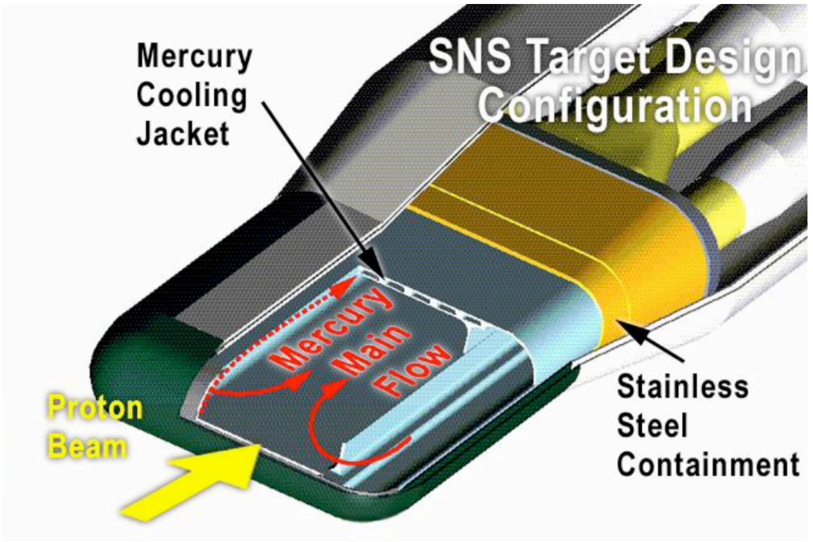
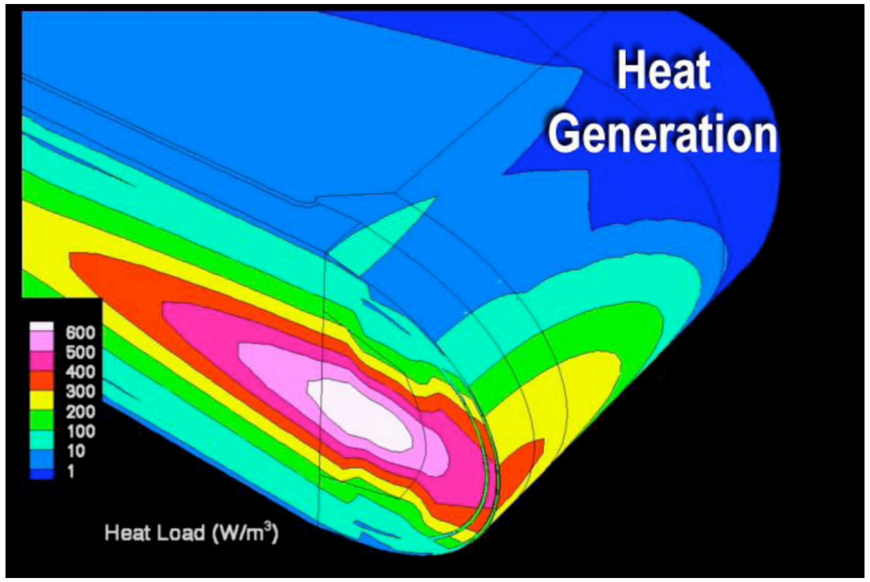
Liquid metal targets





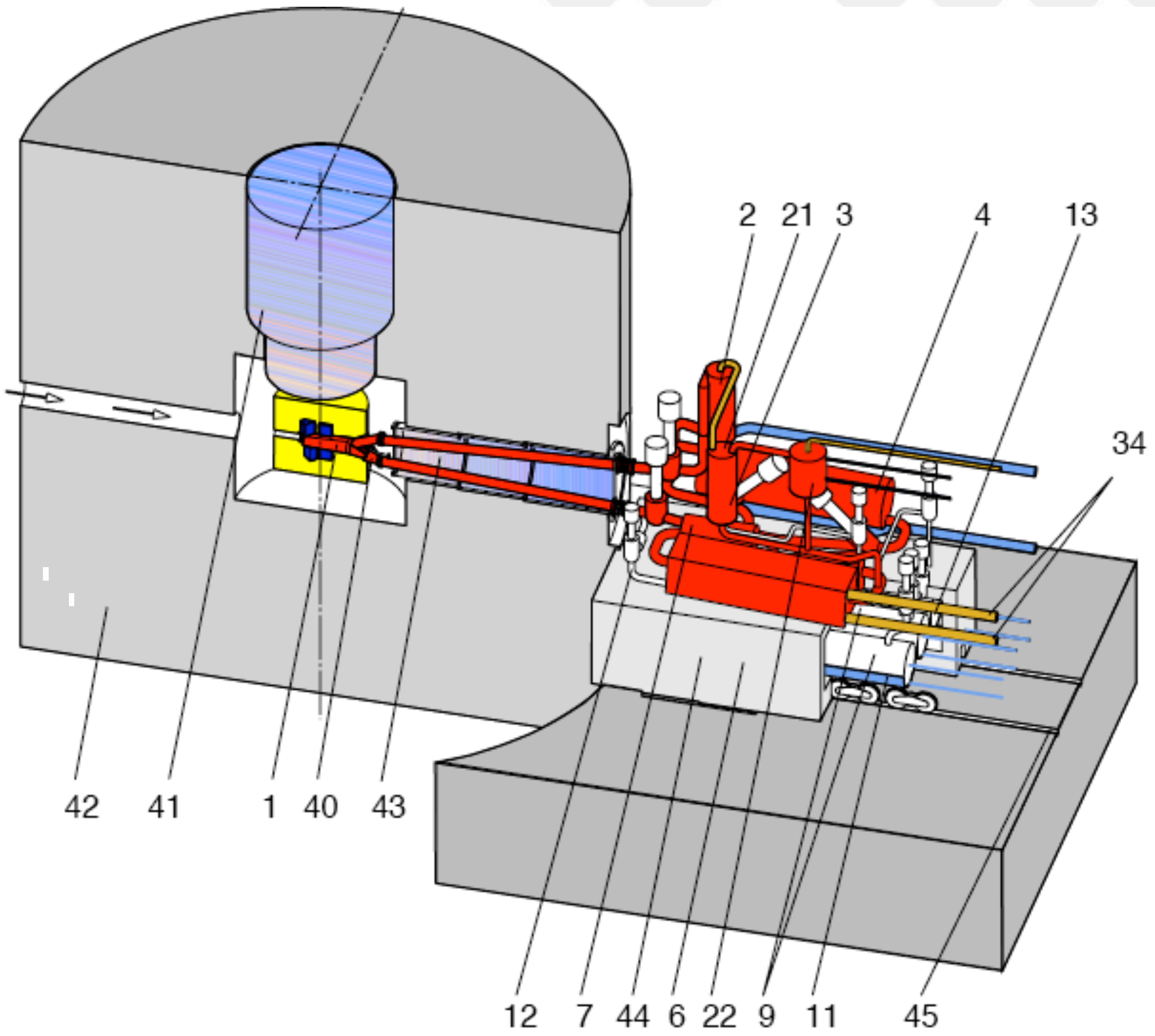


Fig. 4.2.12: *Sketch of the target trolley with drain tanks and primary target loop. In designing and arranging the components of the liquid metal circuit, care must be taken to ensure that the circuit can be completely emptied by gravity and that no gas pockets can form at any point. The numbers 1 to 39 correspond to figure 4.2.11.*

40: reflector-moderator-unit
41: vertical shielding plug
42: shutter shielding
43: horizontal shielding plug
44: trolley
45: rail system

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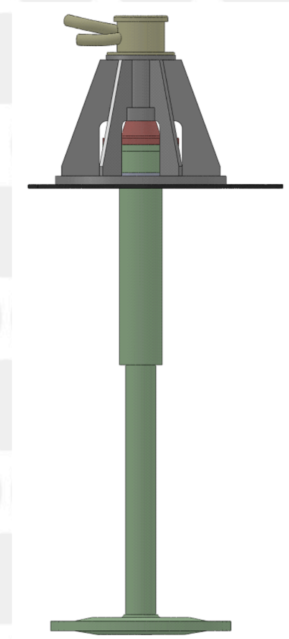
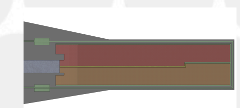
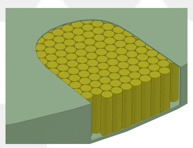
Our view of target development

- Preparatory work is being carried out along two parallel lines on liquid-metal and solid targets to minimize project risks :
- The thermal hydraulic and thermal shock performance due to deposition of 300 kJ on millisecond scales needs to be characterized in much more detail than previously done.
- Work on cavitation mitigation technologies (helium bubbles and gas protective layers) is being carried out in collaboration with SNS.
- Detailed numerical simulations of the pressure and thermal waves are being developed. Particular attention is being paid to the study of effects of thermal cycling aiming to select candidate materials for the vessel able to stand the heat loads.
- The engineering design of a rotary solid 5 MW target is being developed. It considers options such as:
- Embodiment and location of the drive unit
- Target material, possible cladding and disposition (solid block, plates, rods)
- Cooling loop.
- A prototype mockup will be built and tested.



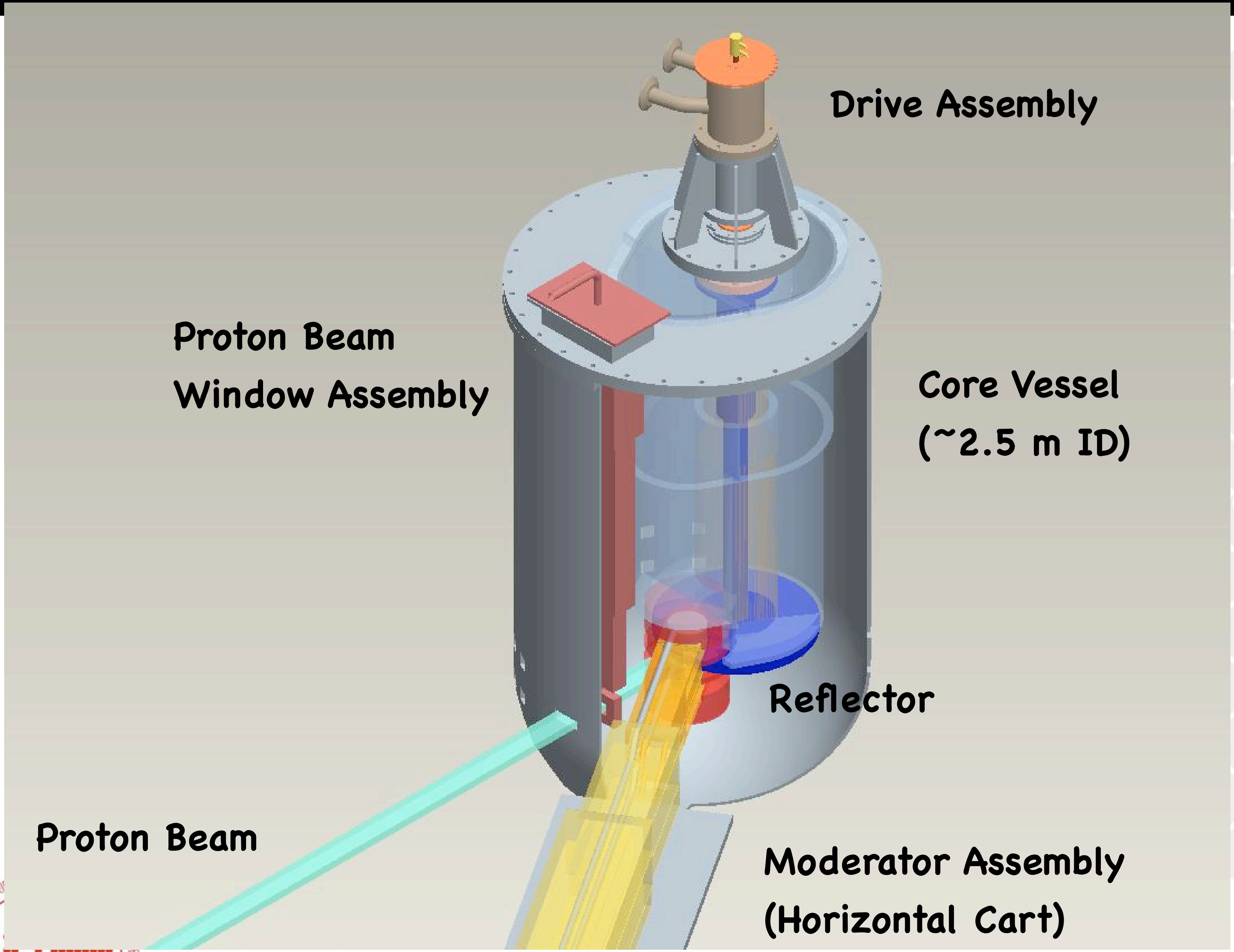
Rod disposition





Towards a MW-range rotating solid target

•



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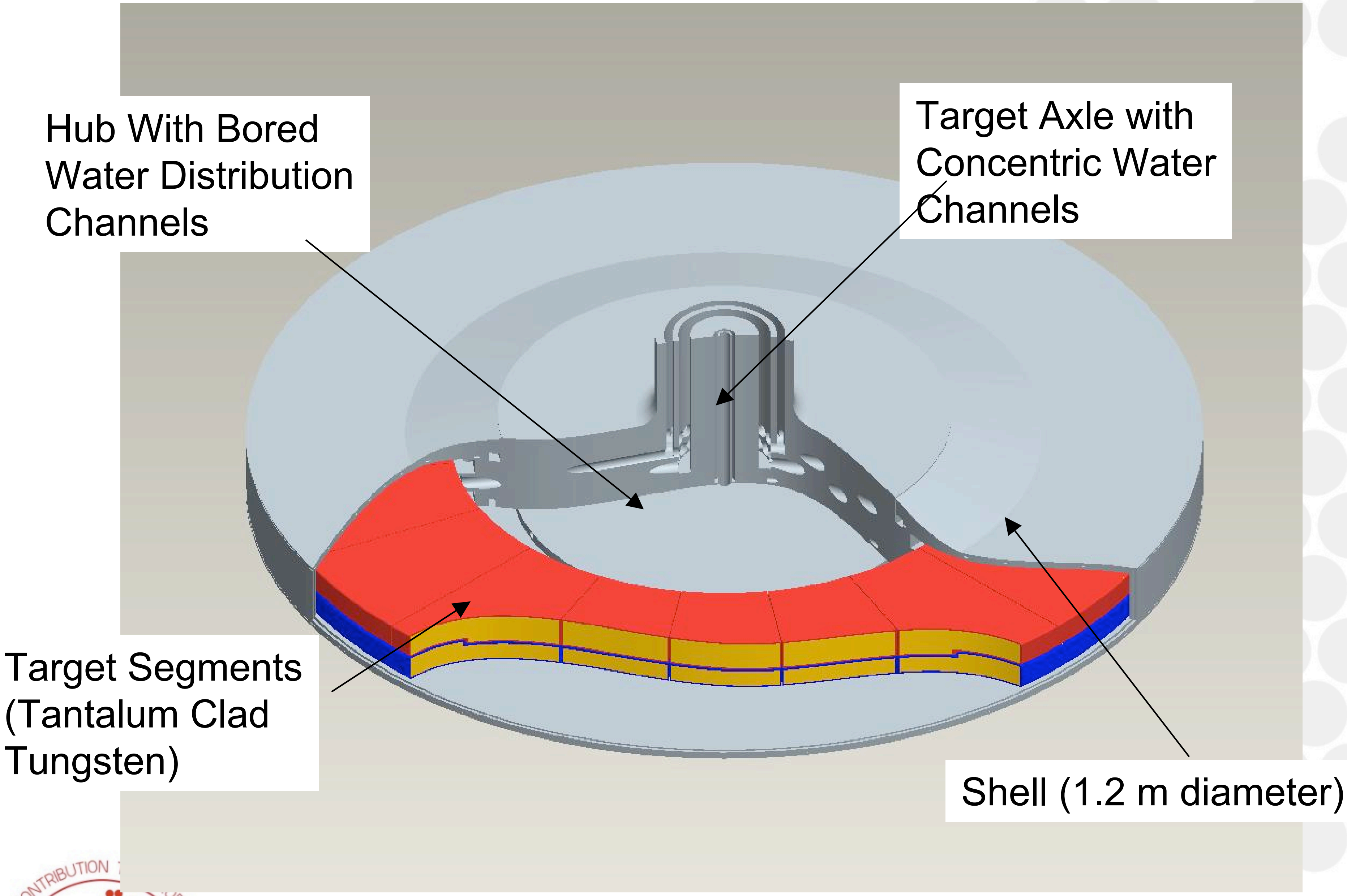
Target Geometry



Our Activities : Current & Plausible

- Development of a conceptual accelerator design in full parametric form (**SNS, IPNO & CEA**),

- Adaptation and prototyping a triple b= 0.35 spoke cavity for high current / pulsed operation (**IPNO**),

- Participation in Linac4 (**CERN**) injector (LEBT & DTL) as well as in engineering development for SPL (HVC Modulators, adaptation of ILC/TESLA Cryomodules),

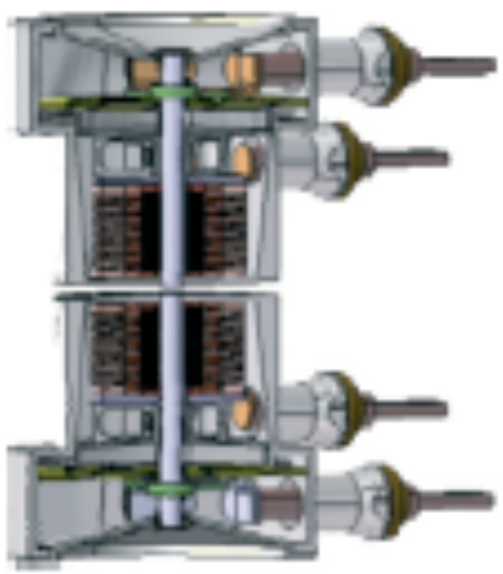
- Ongoing partnership in the development of **ISIS**-FETS,

- Prototyping of a MW-grade rotating solid-metal target (**SNS**),

- Development of thermal-hydraulics studies on target materials to stand heat loads of 300 kJ at high duty factors (3 %) (**SNS**),

- Neutron instruments developments currently under way at **ISIS**, **ILL** (Lagrange) and **PNPI-Gatchina**,

Our view on instrument development



- Prototypes being developed at present at LCMI (Grenoble) and SNS
- Instrumentation requiring rather special needs (12 MW, demanding cooling conditions, instrument to be built within a separate building
- Magnet systems to adapt to a variety of instruments (diffraction, spectroscopy, SANS,Reflectometry)

- ESS-B considers the timing too premature to define an instrument suite at this stage of early planning

- The users will have full power to specify the instrument suite. ESS-Bilbao will set up the adequate user forums to evaluate proposals for new instruments as the source develops

- Care is being taken of to ensure that new instruments with particularly important power and spatial demands such as 35 T magnets, or extreme-conditions machines, can be designed and built

- ESS-Bilbao will be looking for collaboration with other sources for doing prototypes and testing

Collaboration ESS-Bilbao- ISIS Pulsed Neutron Source

- Magnetic LEBT
- Low-level RF controls for the RFQ
- RFQ Tuning system
- Engineering design for the fast (MEBT) chopper
- Beam Dump
- RFQ RF couplers & RF splitting/distribution system
- MEBT Rebuncher,
- MEBT high resolution timing/sync. system

PAC'07

TUPAN111 Proceedings of PAC07, Albuquerque, New Mexico, USA

STATUS REPORT ON THE RAL FRONT END TEST STAND

Alan Letchford, Dan Faircloth, Adeline Daly (CCLRC/RAL/ISIS, Chilton, UK), Michael A. Clarke-Gayther, Ciprian Plostinar, Christoph Gabor (CCLRC/RAL/ASTeC, Chilton, UK), Yi Aaron Cheng, Simon Jolly, Ajit Kurup, Peter Savage (Imperial College of Science and Technology, London, UK), Jürgen Klaus Pozimski (Imperial College of Science and Technology, London; CCLRC/RAL, Chilton, UK), John Back (University of Warwick, Coventry, UK), Javier Bermejo (Universidad del Pais Vasco, Spain), Julio Lucas (Elytt, Spain), Jesus Alonso, Rafael Enparantza

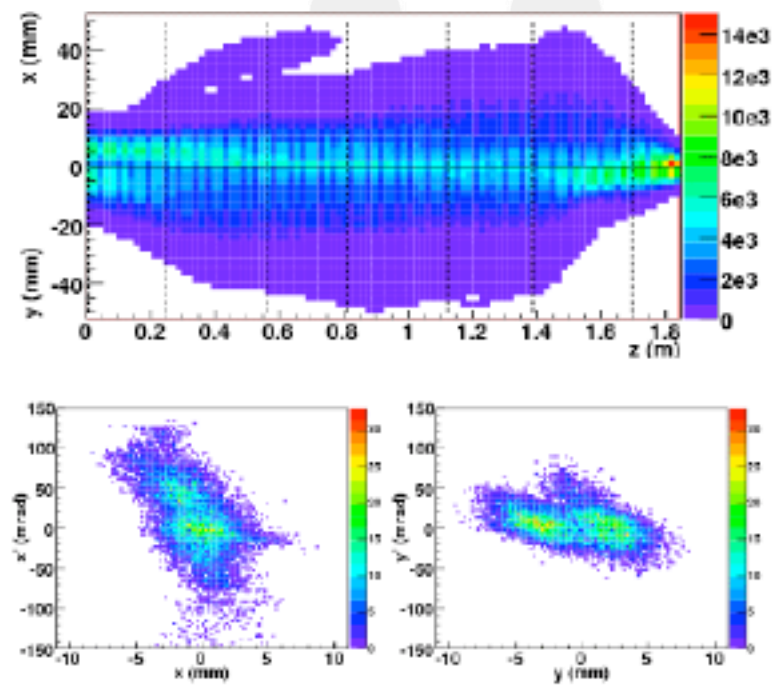


Figure 4: Trajectory plot (above) and output emittances ($\varepsilon_{x,rms}$=0.91πmmmrad; $\varepsilon_{y,rms}$=0.66πmmmrad) in the transversal plane (below) based on LEBT simulations, using the input data from the first pepper pot device ($\varepsilon_{x,rms}$=0.85πmmmrad; $\varepsilon_{y,rms}$=0.86πmmmrad). Dotted vertical lines show the drift and solenoid boundaries.

EPAC'08

STATUS OF THE RAL FRONT END TEST STAND

A.P. Letchford, M.A. Clarke-Gayther, D.C. Faircloth, D.J.S. Findlay, S.R. Lawrie, P. Romano, P. Wise (STFC RAL, Didcot, UK), F.J. Bermejo (Bilbao, Spain), J. Lucas (Elytt Energy, Madrid, Spain), J. Alonso, R. Enparantza (Fundación Tekniker, Elbr, Spain), S.M.H. Al Sari, S. Jolly, A. Kurup, D.A. Lee, P. Savage (Imperial College of Science and Technology, London, UK), J. Pasternak, J.K. Pozimski (Imperial College of Science and Technology, London; STFC RAL, Didcot, UK), C. Gabor, C. Plostinar (STFC ASTeC, Didcot, UK), J.J Back (University of Warwick, Coventry, UK)

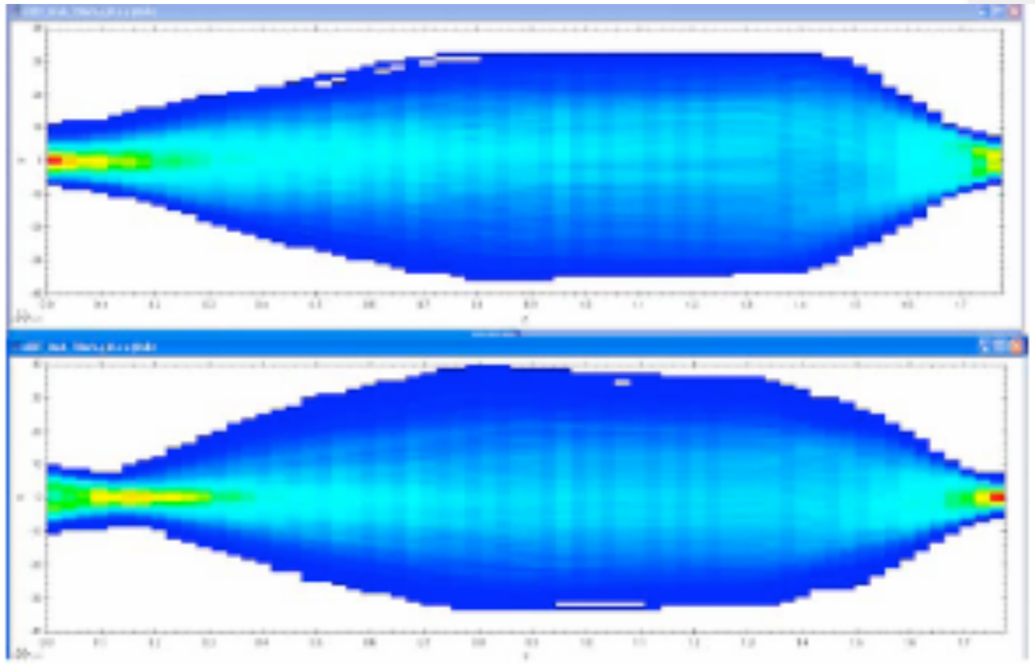


Figure 3: LEBT beam envelopes calculated with GPT.

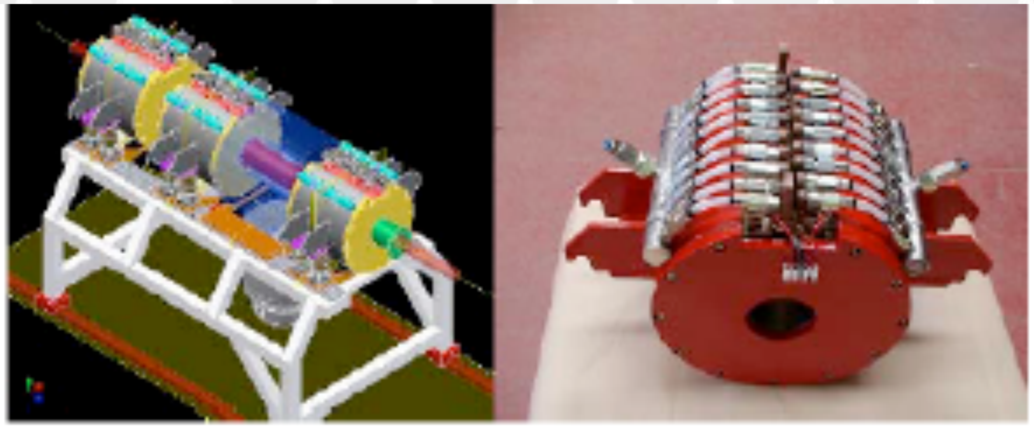
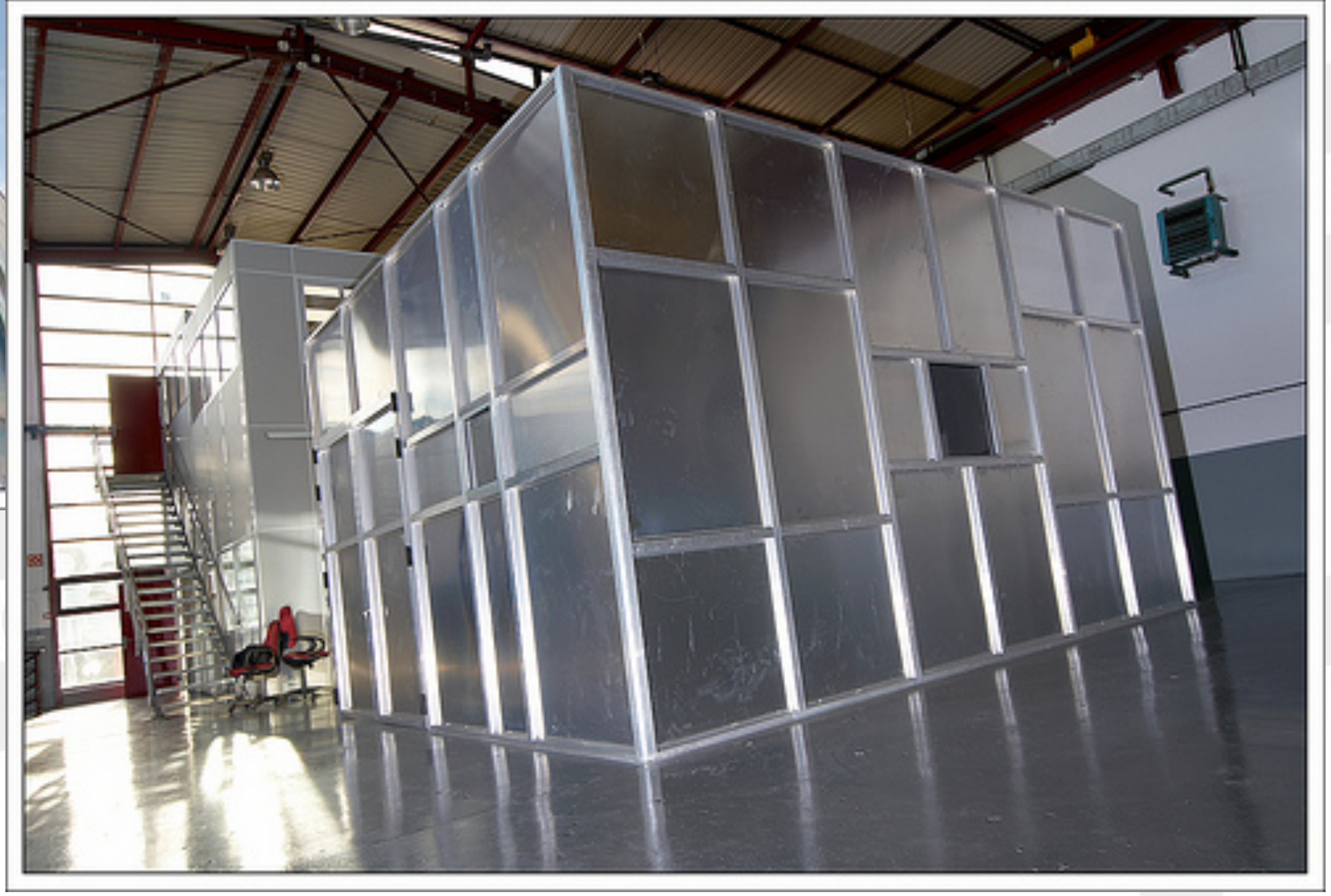


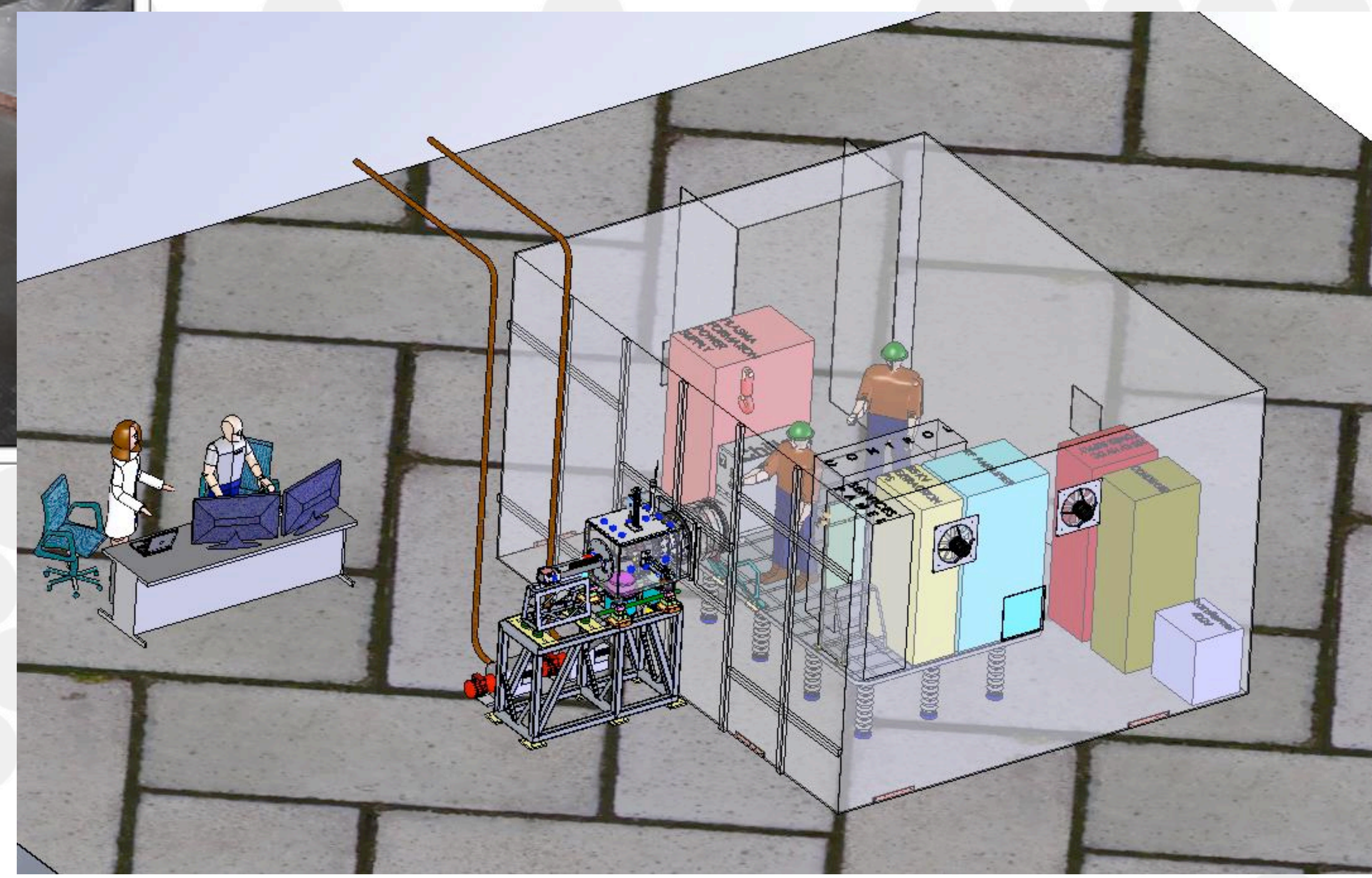
Figure 4: Layout of the FETS LEBT and one of the completed solenoids from Elytt.

Current Activities : In-house developments

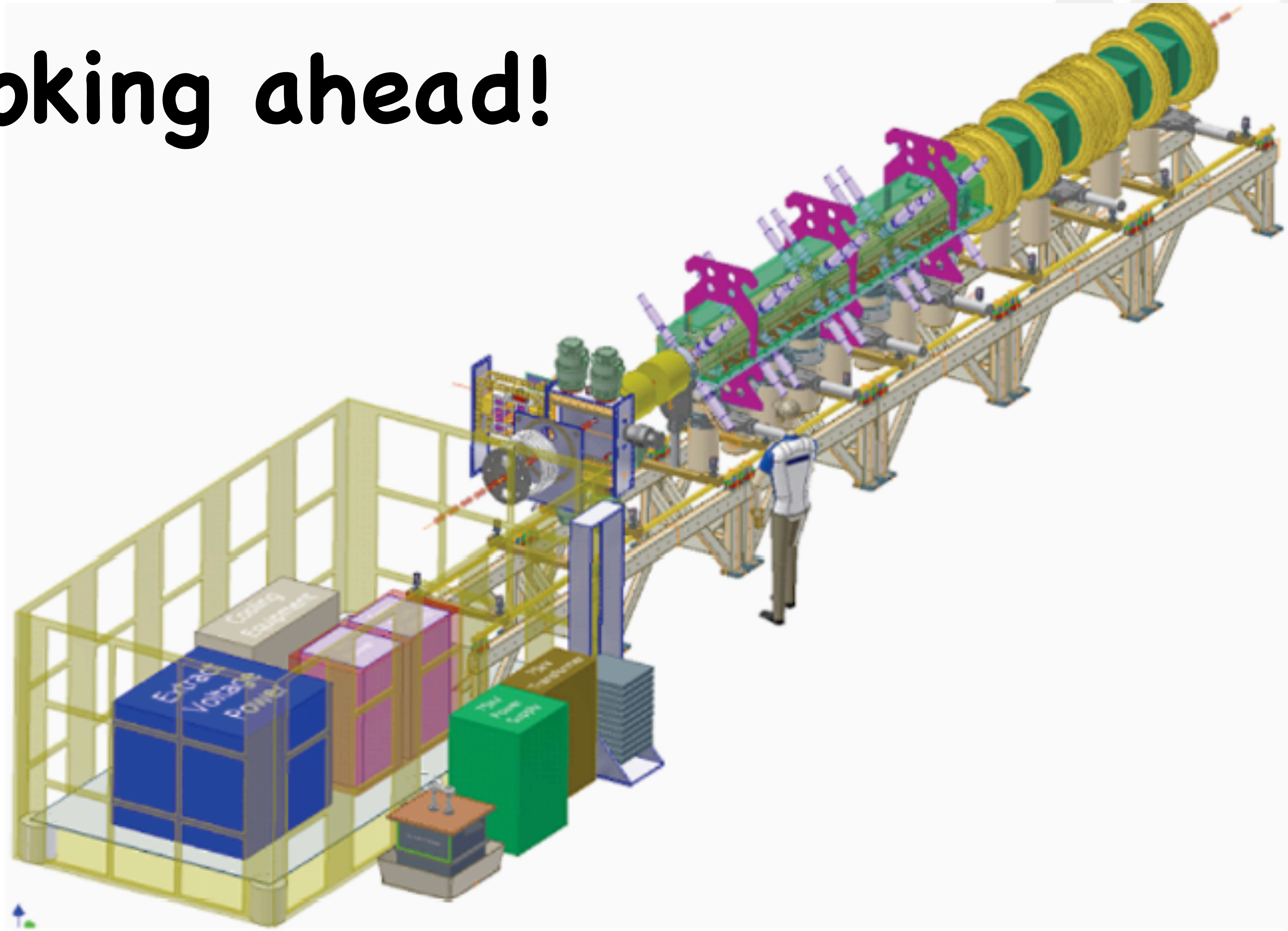
- Development of a versatile Ion Source Test Stand, aiming at the development of our own injector able to test low beta cavities.
- Assembly of a (mostly local) project team on beam dynamics, RF controls, neutronics & fluid mech. issues
- Help to nucleate an industrial base for accelerator components. A base for neutron instrumentation already exists.

The Foundations of our future FETS-Bilbao





Looking ahead!



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- R. Enparantza et al. EPAC'08, Genoa, Italy, Code WEPP080
- A.P. Letchford et al. EPAC'08, Genoa, Italy, Code THPP029
- A.P. Letchford et al. LINAC'08, Victoria, BC, 2008 : "Status of the RAL Front End Test Stand"
- I.Bustinduy et al. HB2008, Nashville, TN, 2008, : "A superconducting proton accelerator for thr ESS-B linac
- R. Enparantza et al. NIBS, Aix-en-Provence 2008: " An Ion Source Test Stand for Ultimate Reliability

Wrap up / Conclusions

- ESS- Bilbao is now in a position to start baselining an up to date accelerator able to deliver a minimum of 100 mA current using already existing technology,
- Reaching the 150 mA current as written in the spec. will require a modest R&D effort, mostly geared towards finding available options for compensation of space-charge effects at the front-end,

ESS-BILBAO INITIATIVE

An International knwoledge community at the service of Europe

THANKS FOR YOUR ATTENTION

References

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