RT options for low energy part of Project X linac

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The same problem six years later

General layout of proton driver front end. Variants.

RFQ,0.5-3 MeV	MEBT, chopper?	3-10 Mev, Acc. Str.?	10 – 400 MeV, Spoke
SNS, 402.5 MHz, 2.5 MeV JHF, 324 MHz, 3 MeV	SNS, traveling wave JHF, standing wave low Q cavity Laser chopper. Power? Chopper at higher energy?	Single spoke, β = 0.12 ? Half wave cavity. ? DTL Quad. focus.? SDTL Effectiveness? Individual cryostat for each SC solenoids? Some new RT cavity ??	Beyond 10 MeV linac has no apparent fundamental problems

Today is known as SSR0

Today is known as RT CH. That time we chose them.

7/28/2004

Some proton machine projects and test facilities (dead and alive, and reviewed)

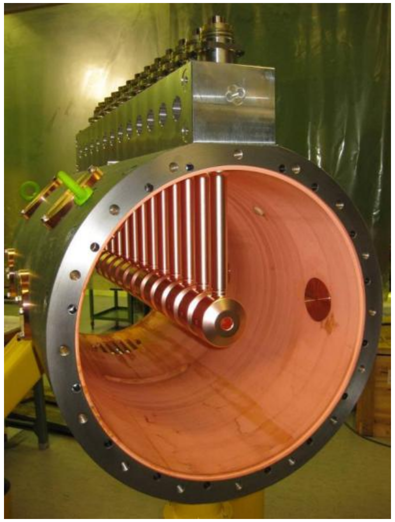
- CONCERT – Combined Neutron Center for European Research and Technology
- SNS – Spallation Neutron Source
- ESS – European Spallation Source
- SPL – Superconducting Proton Linac
- Linac4 at CERN
- KOMAC – Korean Multipurpose Accelerator Complex CW
- FAIR – International Facility for Antiproton and Ion Research
- EURISOL – European Isotope Separation On-Line CW
- IPHI – High Intensity Proton Injector
- TRASCO – TRAnsmutazione di SCOrie CW
- HIPPI – High Intensity Pulsed Proton Injectors
- XADS – eXperimental accelerator Driven Sysytem CW
- EuroTrans -EUROpean research program for the TRANSmutation of High Level Nuclear Waste in an Accelerator Driven System. CW
- IFMIF – International Fusion Material Irradiation Facility (D+) CW
- J-PARC – Japan Proton Accelerator Research Complex
- JAERI NSP - Japan Atomic Energy Research Institute Neutron Science Project CW/Pulsed

All these proton linacs use DTLs of different designs in their low beta parts. TRASCO is the only exclusion - it uses SC re-entrant cavities right after RFQ.

Why DTLs?

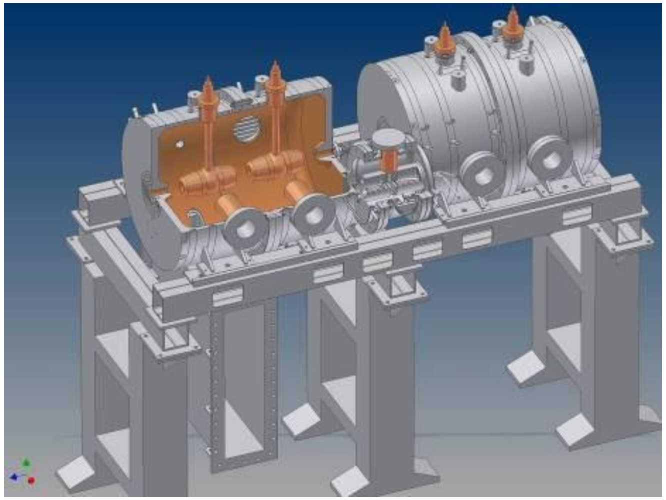
For all machines the major challenge is in the low energy part (up to 20 MeV), were the beam quality is defined, leading to possible losses in the high-energy part of the accelerator then activation preventing hands-on maintenance. Usually **DTL provides the best beam dynamic,** and it is a conservative and reliable choice. But today the choice between SC and room temperature structures already exists for all the energies range, including RFQ's. The optimum design of an accelerator depends upon its detailed specifications.

Classical DTL



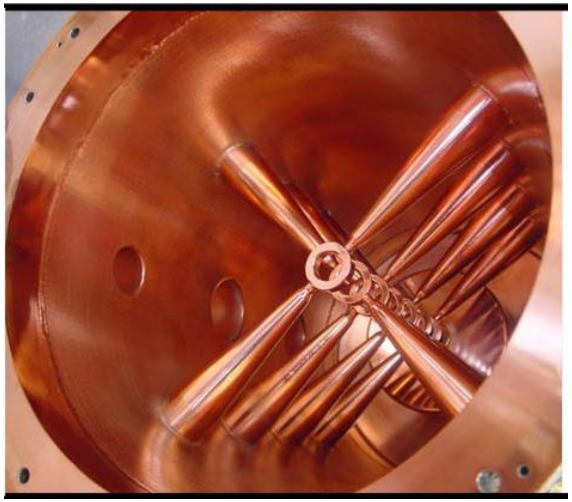
Classical DTL, the workhorse of linacs since 1946. Almost mandatory for high current machines.
Main problem – focusing elements in drift tubes.

SDTL and CCDTL



Much more effective, simpler and cheaper. More problematic beam dynamic because of longer focusing periods. So, usually they are used for higher beta than DTL.
Exception interesting for us – KOMAC CCDTL.

CH DTL

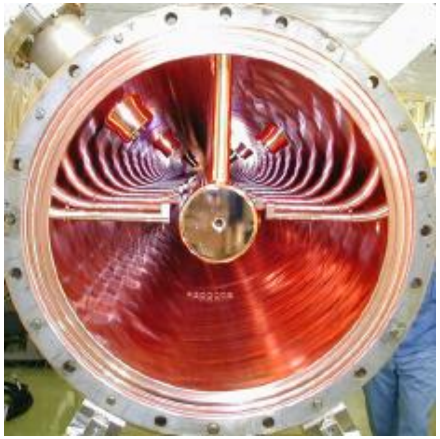


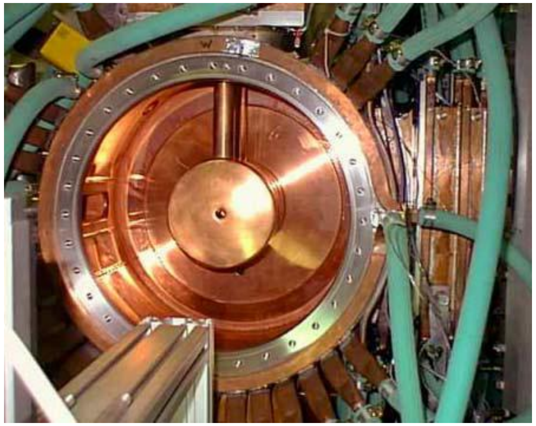
CH DTL is the most effective structure of the kind. Special beam dynamic allows relatively long focusing periods required by the TE mode of operation, but the beam has to spend long time in non-linear regions of phase space. It's a weak point.

Examples of DTLs with parameters close to PrX

	J-PARC	IPHI	KOMAC (option)
Frequency, MHz	324	352	350
Input energy, MeV	3	3	3
Output energy, MeV	10	11.6	11.45
Length, m	4.2	5.75	≈ 8 (two tanks)
RF power*, kW	450	306	280
Acc. Gradient, MV/m	2.5	1-1.75	<1
* Including margin	+30%	+25%	+25%


J-PARC DTQ coil


J-PARC DTL1


IPHI test DTL. Tested at full CW power.

Coupled Cavity DTL (LANL, 1994?) and Separated DTL (KEK, 1992)

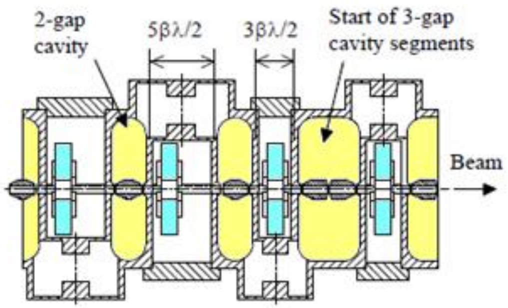
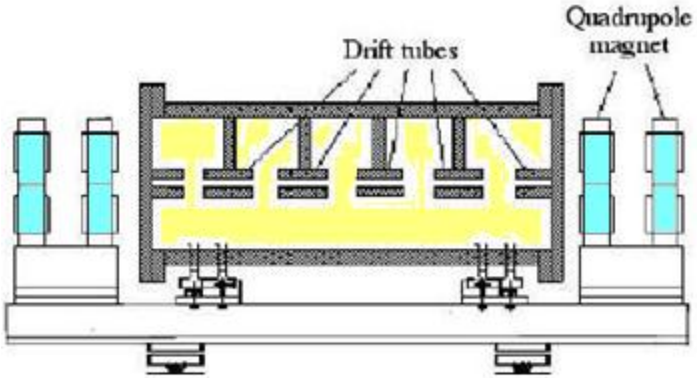
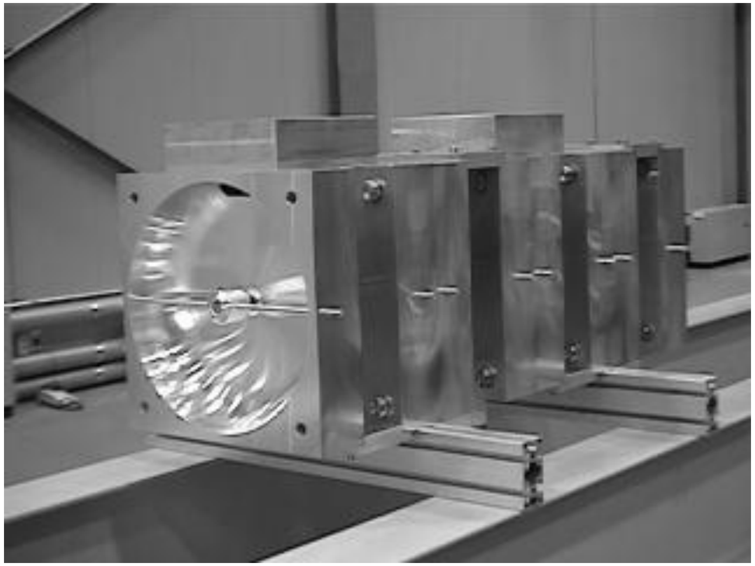


Figure 2. The transition from one-drift-tube, 2-gap cavities to two-drift-tube, 3-gap cavities occurs at about 8.1 MeV. The quadrupole magnet is as far upstream as possible in the last 5βλ/2 space.

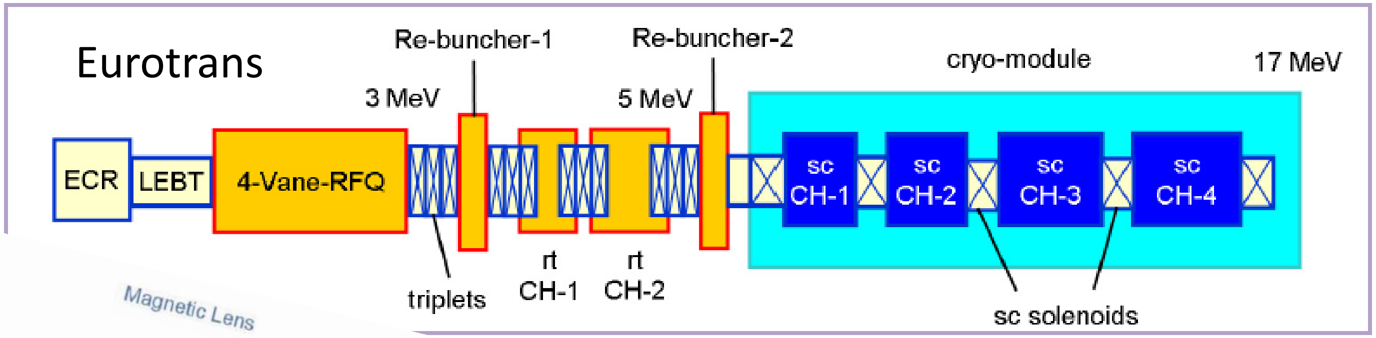


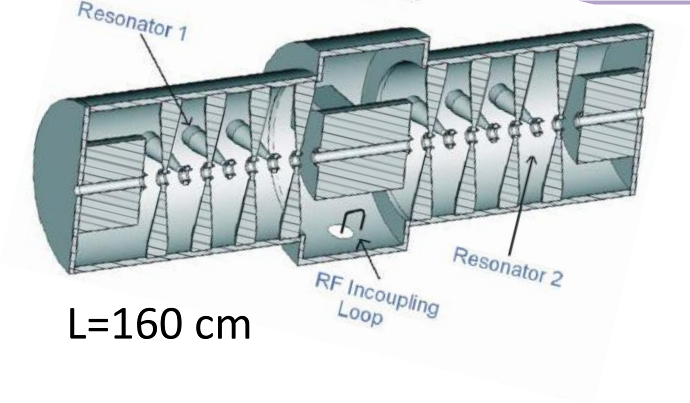
KOMAC CCDTL – the only example suitable for us

	KOMAC SSDTL
Frequency, MHz	2x350=700 **(!)**
Input energy, MeV	3
Output energy, MeV	10 (nominal 20)
Length, m	≈ 10 (nominal 25)
RF power*, kW	224 (nominal 1.15 MW)
Acc. Gradient, MV/m	<1
* Including margin	+25%



Cross-bar H-type DTL (CH DTL)





L=160 cm

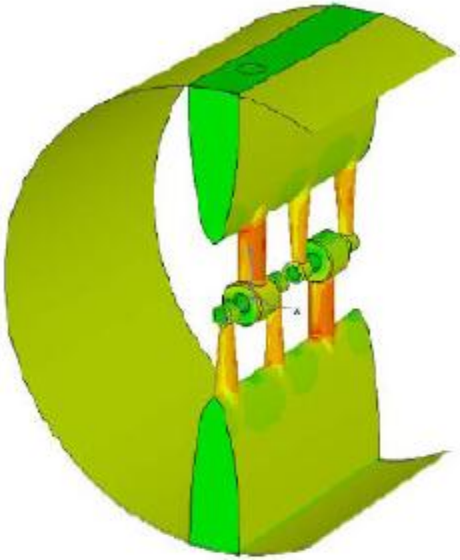
In EuroTrans 8 MeV RFQ has been replaced with 3MeV-RFQ and a room temperature CH-DTL. There are two main reasons: 1) normally at the end of the RFQ there are some unwanted (wrong charge–to-mass ratio) or not well accelerated, but transported particles which have high chances to be lost in the downstream linacs. Because for avoiding breakdown a superconducting linac just permits very low beam losses, a room-temperature CH-DTL could be a good “filter”. 2) After 3MeV, an RFQ is not efficient as a DTL for acceleration. Therefore, the new proposal has the advantages of saving the total structure length as well as the costs.

	FAIR, 38% duty factor
Frequency, MHz	325
Input energy, MeV	2.91
Output energy, MeV	11.6
Length, m	1.08 (without triplets)
RF power, kW	852
Acc. Gradient, MV/m	8

Too high for CW!

Other ideas…

TE-mode structures with PMQs
S. S. Kurennoy, S. Konecni, J. F. O'Hara, L. Rybarcyk, EPAC08



A combination of the high shunt impedance of TE modes (in this case IH, TE110) with a classical beam optics ensuring low beam losses and minimum emittance growth.

Possible now because we have compact permanent quadrupoles (but probably we need EMQ for CW) that fit into small drift tubes, and we have 3D RF simulation codes that allow designing complicated structures.
To be investigated for the energy range 3 – 10 MeV, applied to the CH for CW.

Conclusion (a personal one, not required to be objective)

- If we focus on the low energy part of the machines, one can observe that most of the choices that were made world-wide are conservative. Few projects accept major risks in the designs which can be costly and/or unreliable. Teams use the “well known” principle, and small progresses are made at each new project.
- The conventional DTLs are gradually replaced with the H-cavities with higher voltage gain, higher efficiency, and lower number of elements, with significant improvement on focusing lenses alignment (IFMIF, EURISOL, EUROTRANS, etc).
- A front end design based on CH-DTLs followed by a series of superconducting CH structures is expected to be popular.
- A short room-temperature structure between RFQ and SC linac is necessary to minimize the risk associated with the unwanted particles out of the RFQ (non-accelerated, different charge–to-mass ratio, etc). At least until we are confident that the risk doesn’t exist.
- A research for better DTL design will continue.