Light Ion Linac for 7 MeV/u.

BEVATECH GmbH
Holger Höltermann

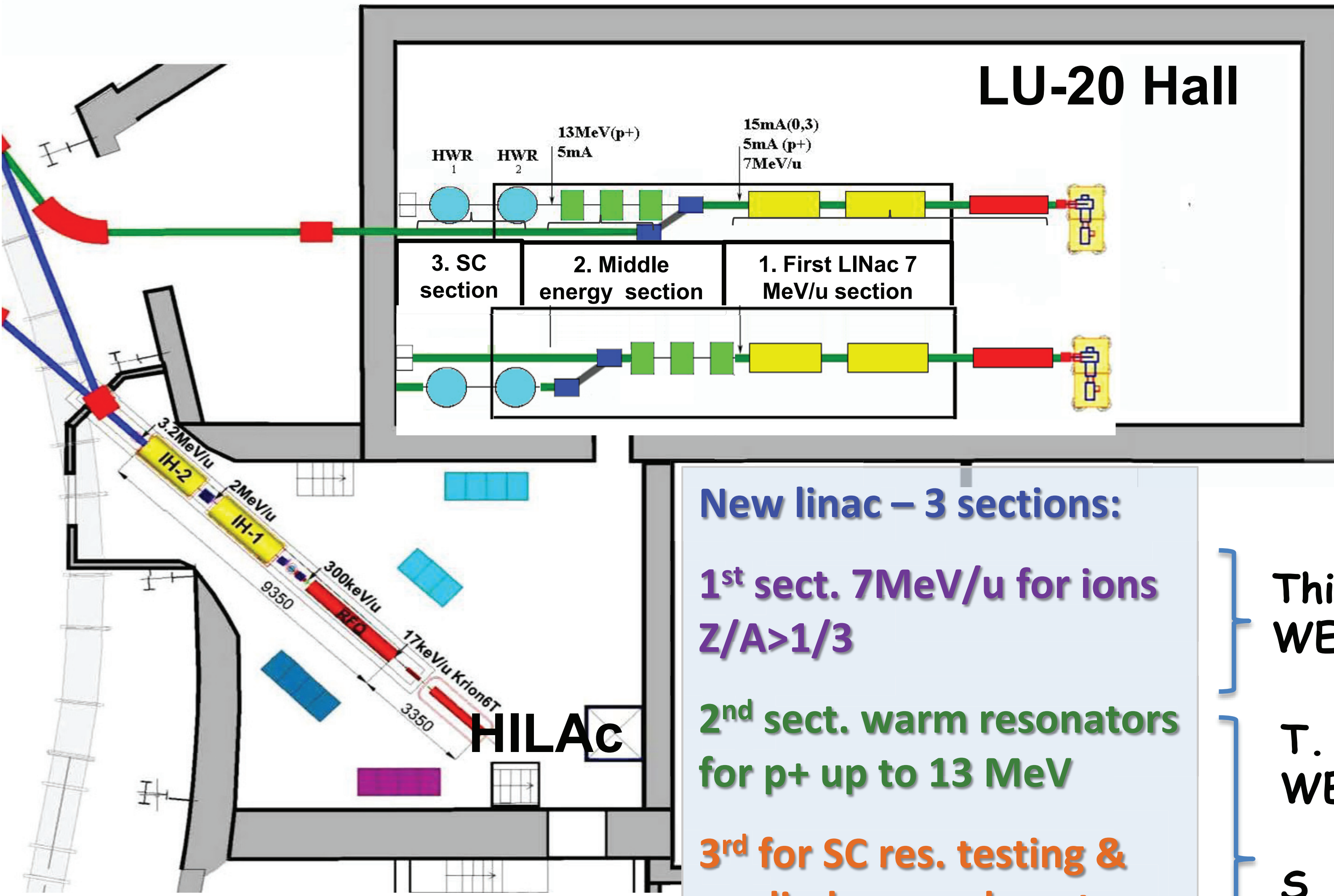
On behalf of the team from LHEP/JINR and BEVATECH

BEVATECH

NICA

RuPAC 2018, Protvino, Russia 01.- 05. October 2018

New Light Ion Linac "*LILAc*" Injector for the Nuclotron



New linac – 3 sections:

1st sect. 7MeV/u for ions Z/A>1/3

2nd sect. warm resonators for p+ up to 13 MeV

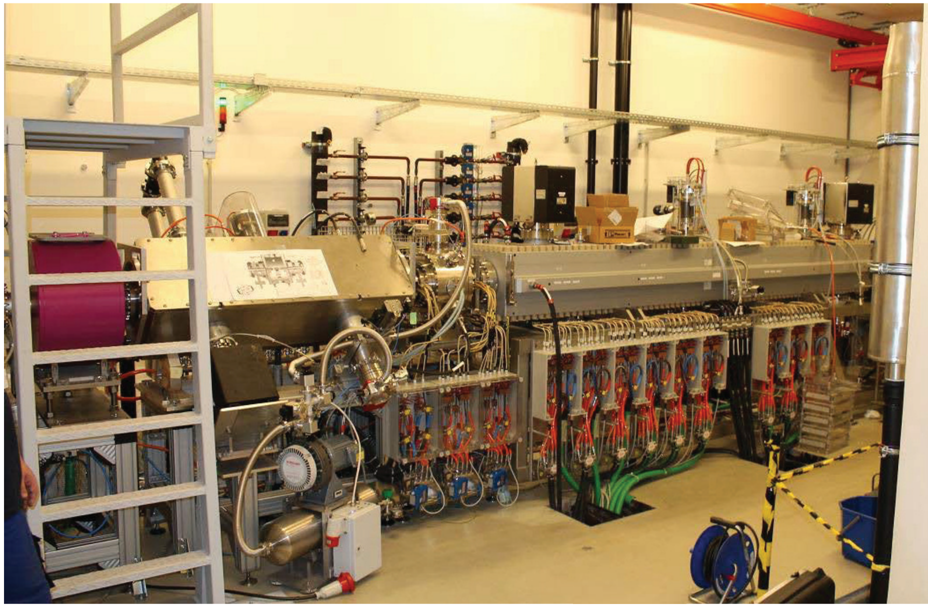
3rd for SC res. testing & applied research up to 20MeV

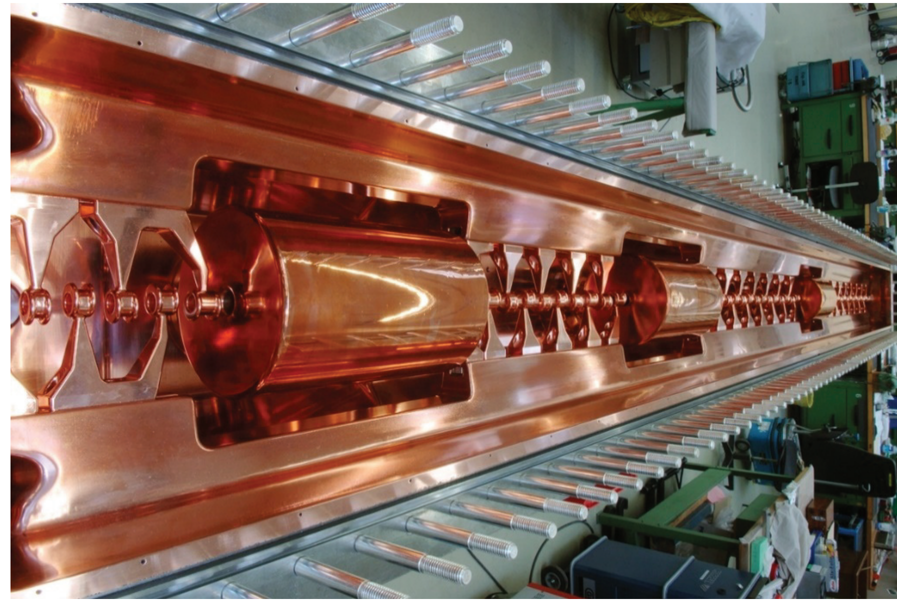
This Talk WECAMH02

T. Kulevoy WECAMH01

S. Polozov WECBMH01

7 MeV/u. Injectors at industrial scale





UniversitätsKlinikum Heidelberg

MedAustron

UKGM
UNIVERSITÄTSKLINIKUM MARBURG

fondazione CNAO
Centro Nazionale di Adroterapia Oncologica per il trattamento dei tumori

SPHIC
Shanghai Particle and Heavy Ion Therapy

Accelerators for 7 MeV/u. are today wide spread for the use in ion therapy

Advantage:
- Reliable system design

Draw backs:
- **Current limitation für science projects**
- **Due to medical certification design is > 10 years old**

NICA

Light Ion Injector NICA – 1st part

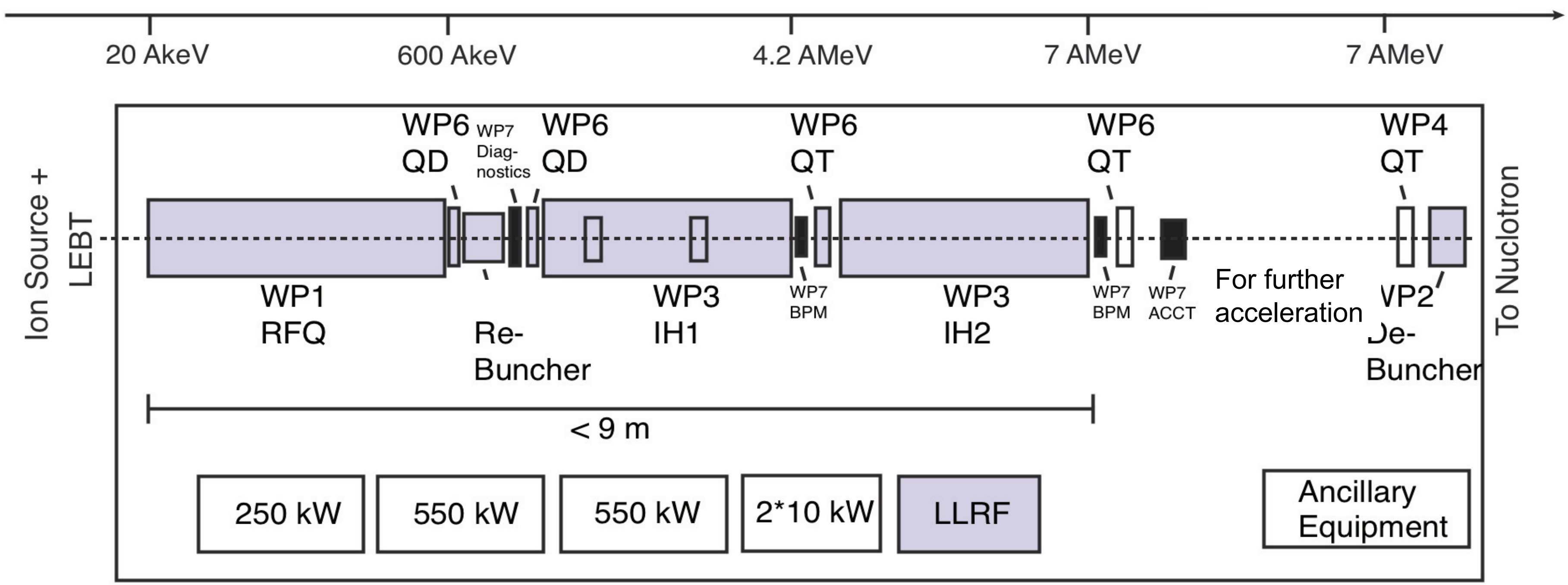
Parameter	LILAC (TDR) 20keV	LILAC (Discussion) 30keV
A/q (max)	3 for 15 mA C^{4+}	3 for 15 mA C^{4+}
A/q (min)	1 for 5 mA protons	1 for 5 mA protons
Frequency	162.5 MHz	162.5 MHz
RF amplifier (RFQ/IH)	200 kW / 500 kW	250 kW / 550 kW
Repetition rate	5 Hz	5 Hz
Max. pulse length RF	300 µs	300 µs
Pulse length beam	30 µs	30 µs
E_{in} RFQ/E_{out} RFQ	20 AkeV / 600 AkeV	30 AkeV / 600 AkeV
Transmission RFQ	90 %	90 %
RFQ length	2.1 m	3.3 m
E_{out} IH-DTL (2xIH)	7 AMeV	7 AMeV
Total Transmission HILac after LEBT	≥80 %	≥80 %
ε_{in} (trans, norm)	0.15 π mm mrad	0.15 π mm mrad

Design Parameter LILAC

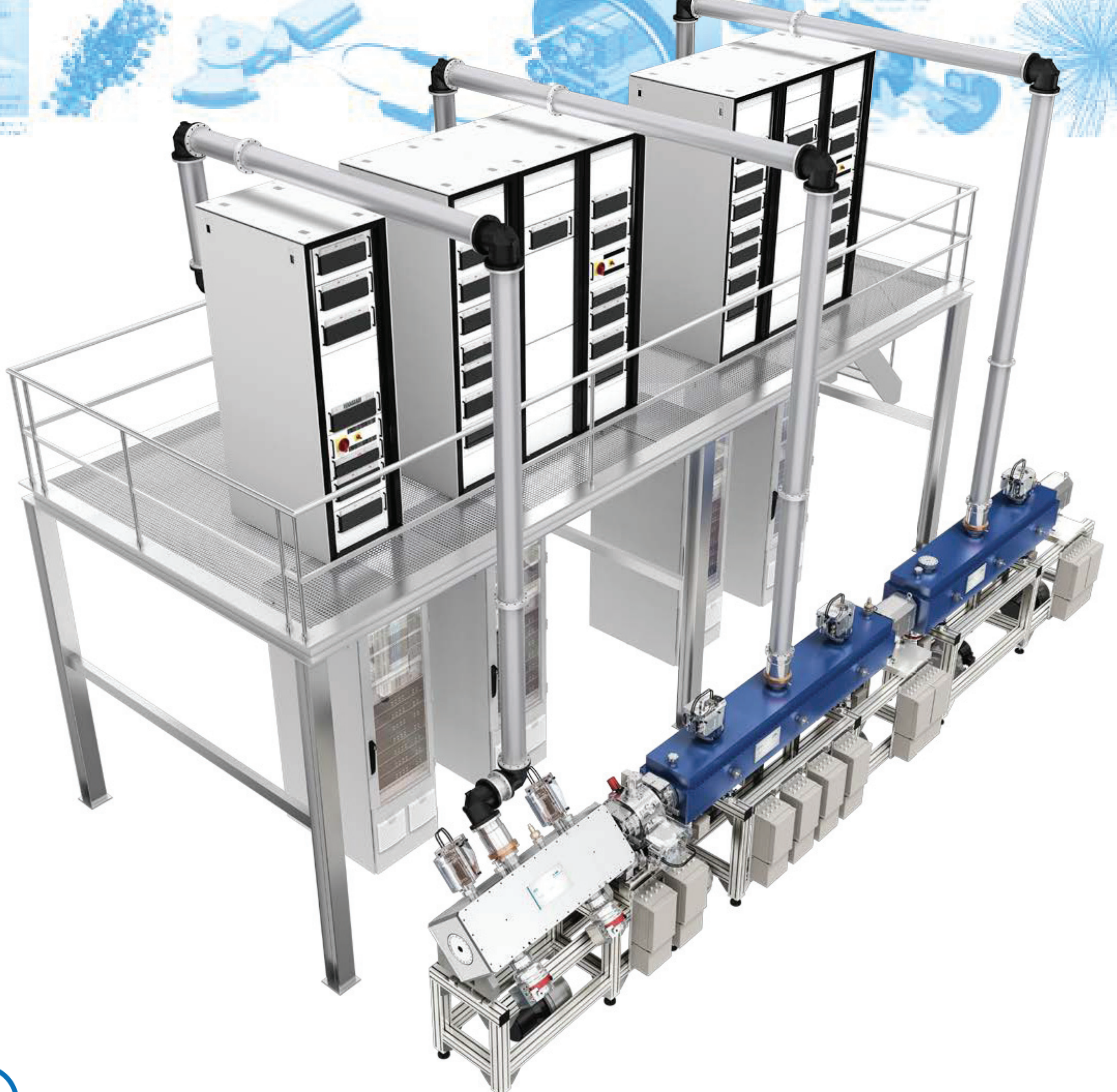
Simulations are performed between 0 mA and 30 mA

NICA – LILac Scheme

Light Ion LINAC normal conducting part

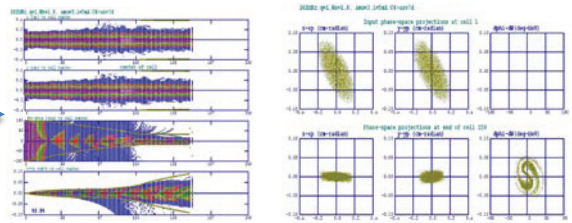


Adapt to most recent cavity designs and materials
Improve on know design issues
Use state of the art RF and electronics technology



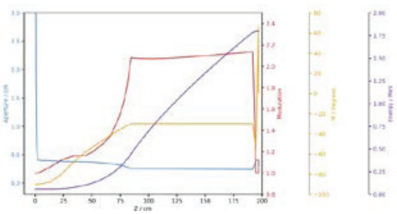
RFQ Design Workflow

Beam Dynamics



IH & overall LINAC design

Electrode Design



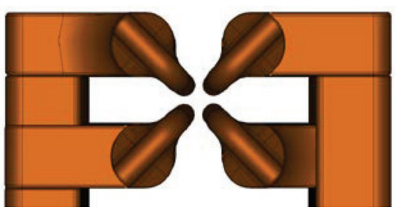
Parameters

Electrode Radius

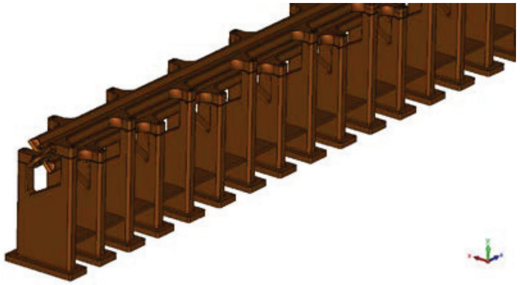
Aperture

Cell Length

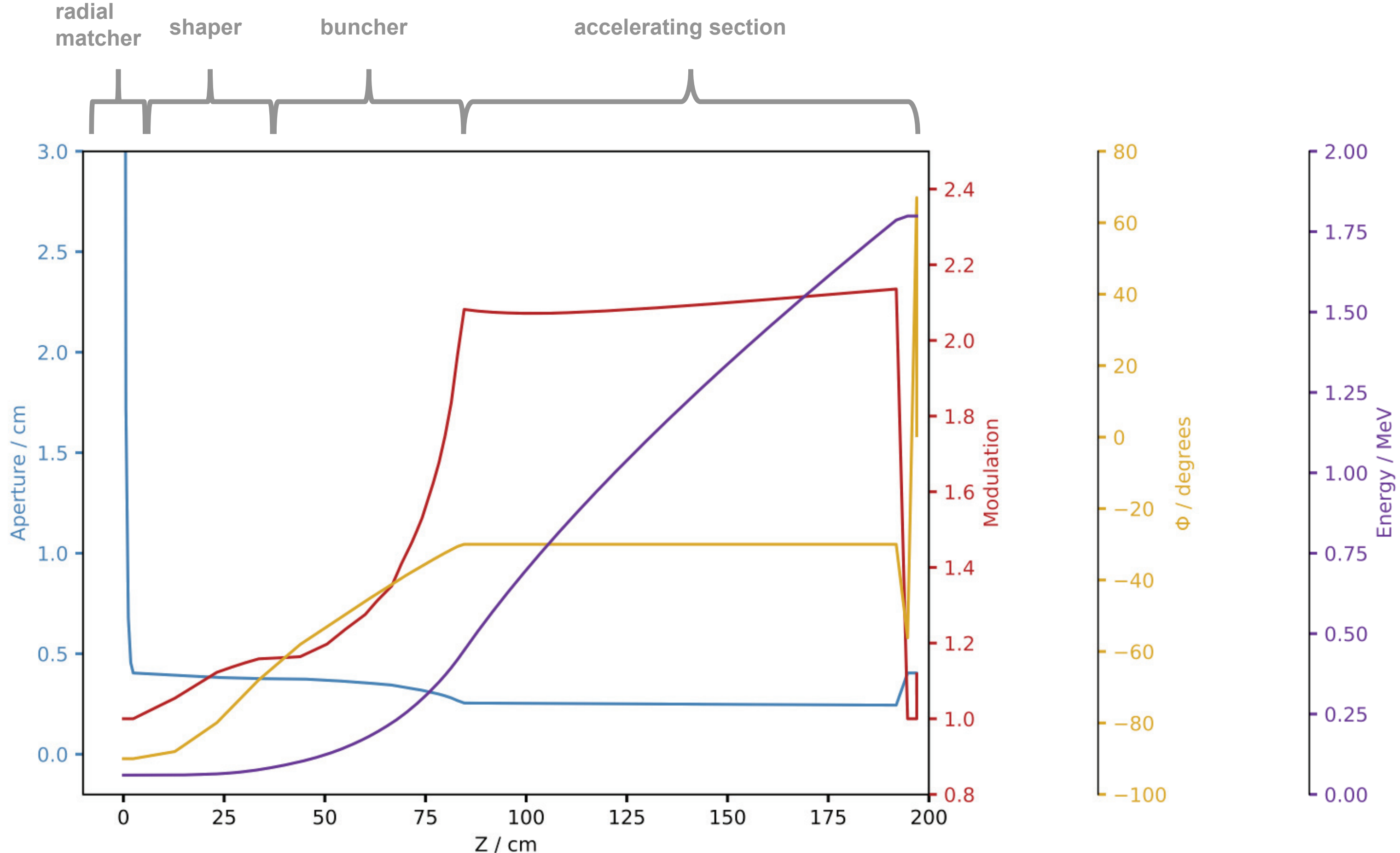
Electrode Voltage

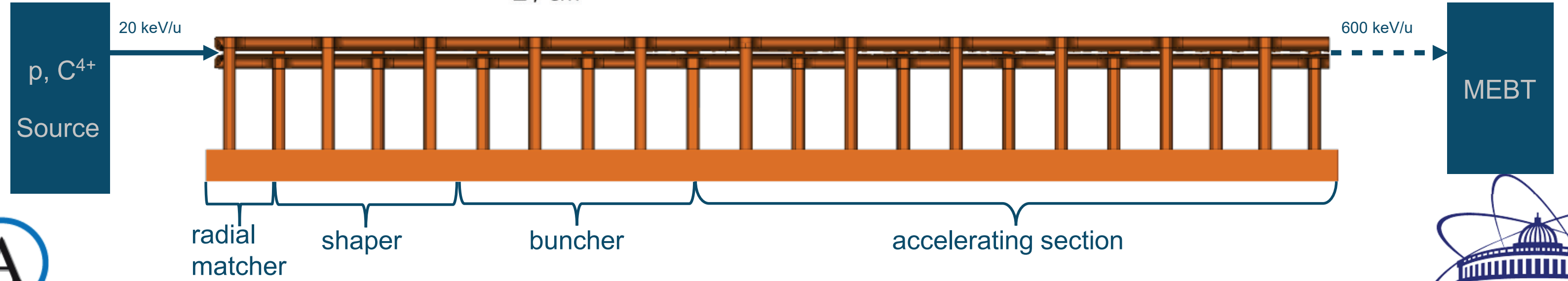


RF Design

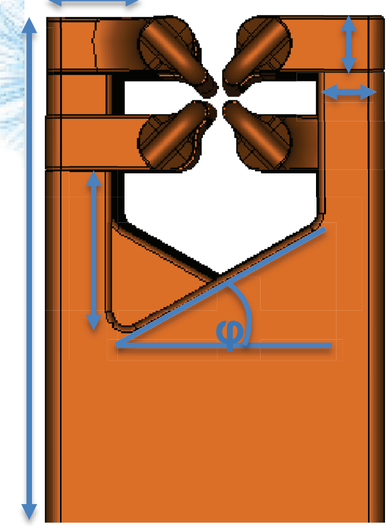


RFQ Electrode Design





RF Design



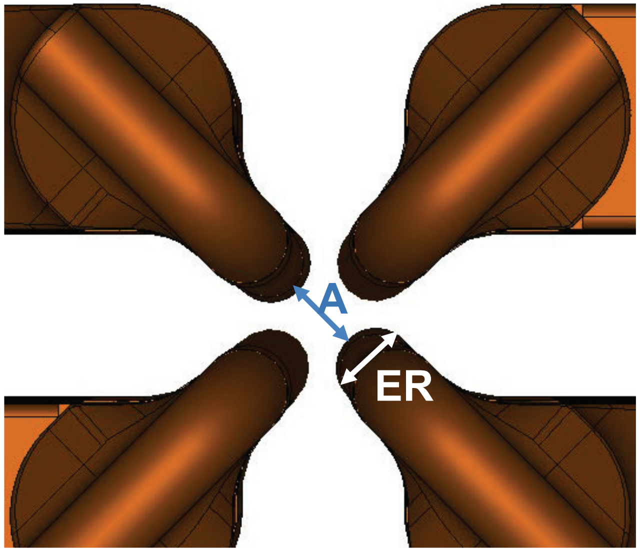
Given by beam dynamics
r0, Rho, m, a, L

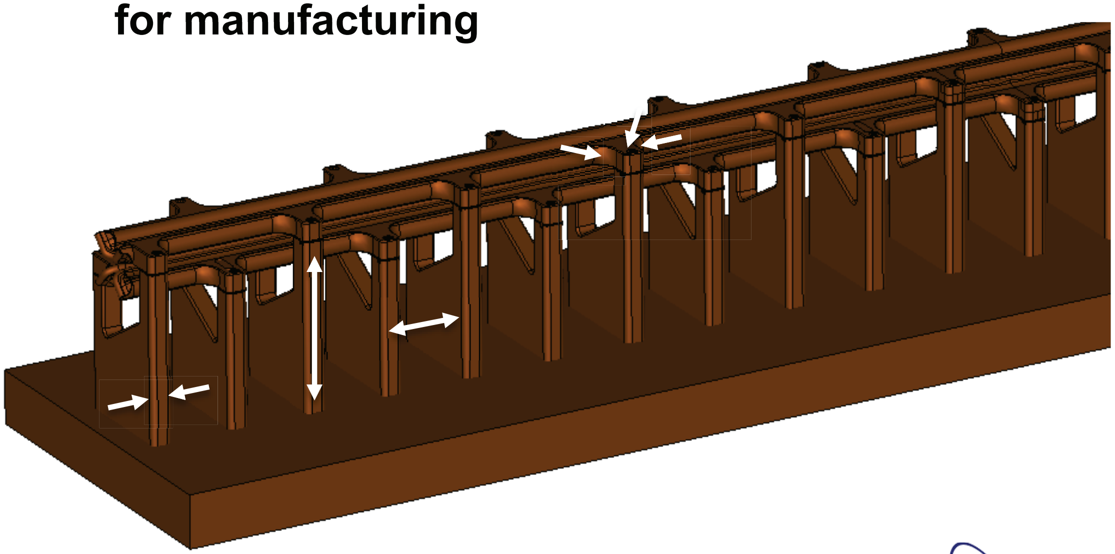
↓

mean aperture
electrode radius

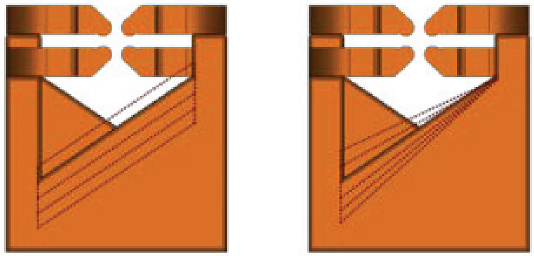
Frequency adjustment
Stem distances
Stem high
Stem thickness
Connection from electrodes to stem

Followed by optimization of shunt impedance and mechanics for manufacturing

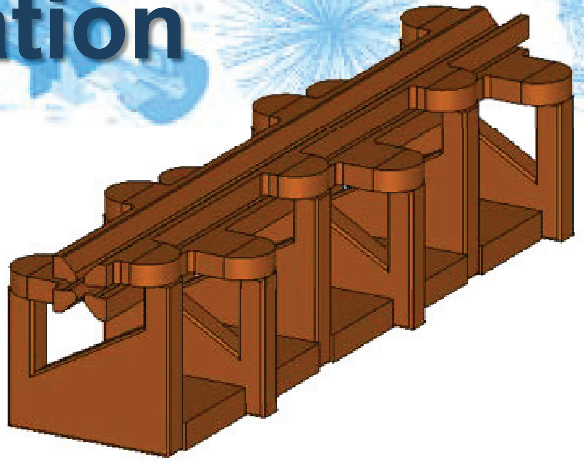


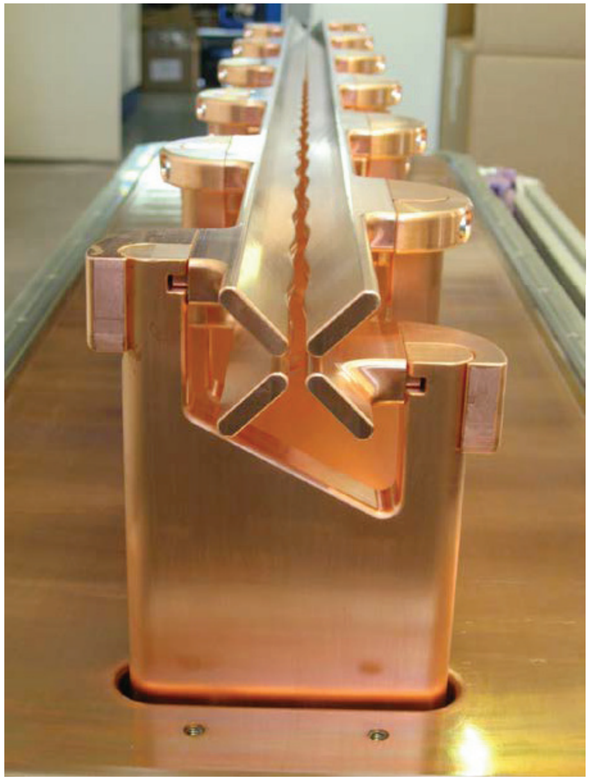


Dipole Compensation



Stem cutting

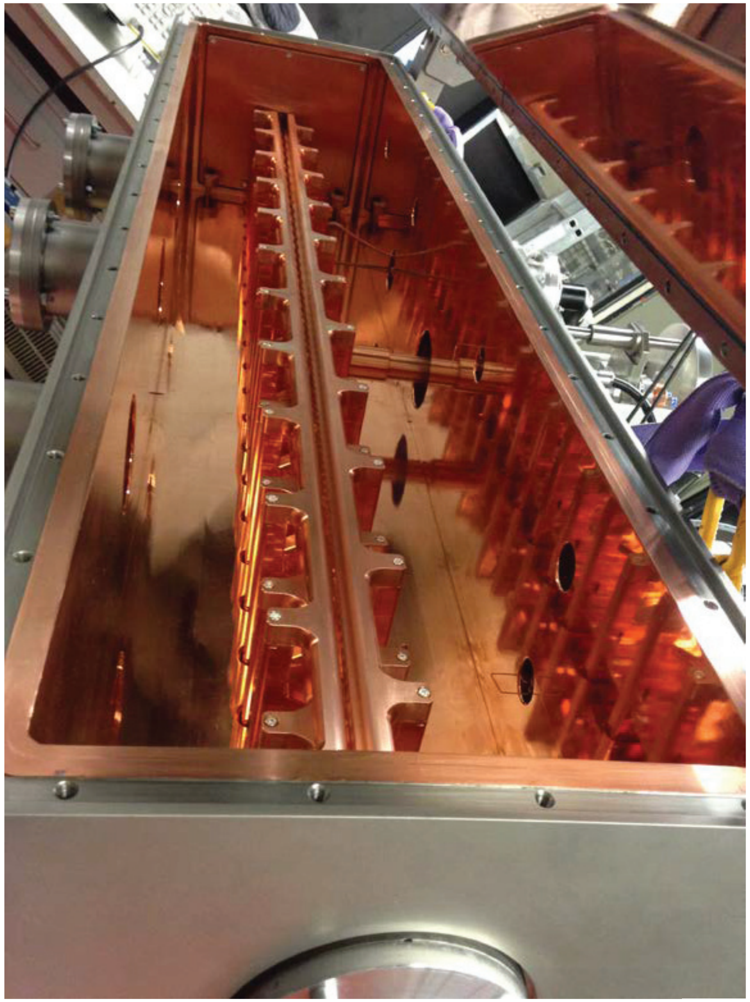




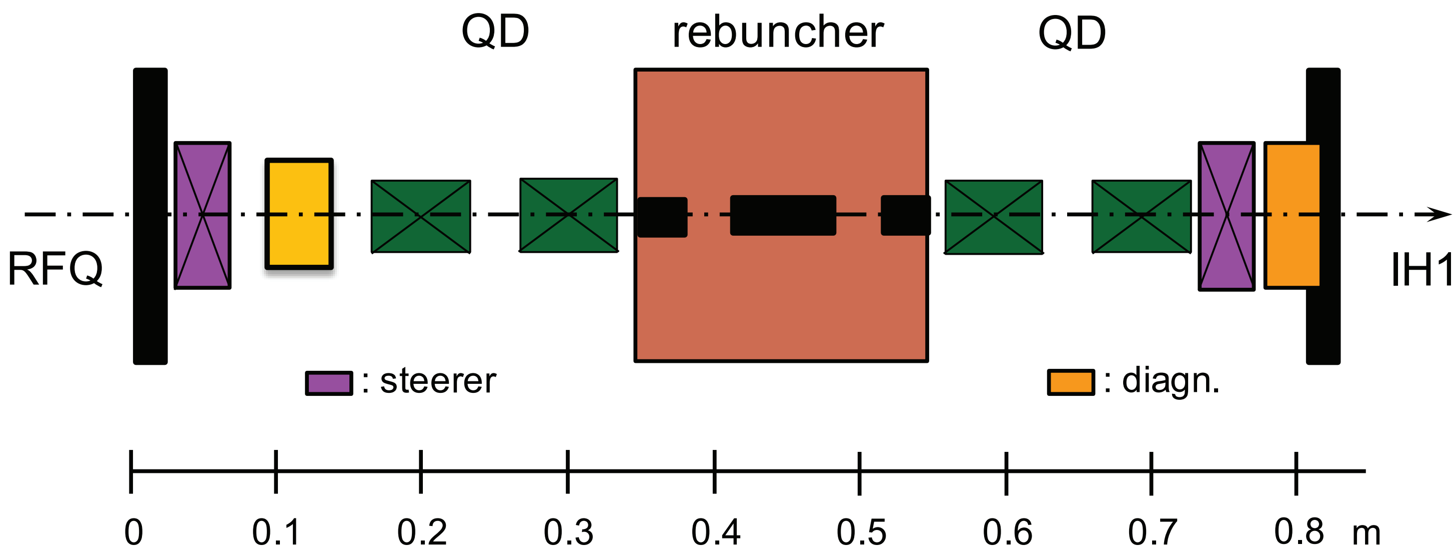
Stem offset

Mechanical Design

Parameter	Value	Unit
Tank Width	400	mm
Tank Height	400	mm
Tank Inner Length	2000	mm
Tank Wall thickness	30	mm
Electrode Length	1980	mm
Beam Height in Tank	175	mm
Stem Distance	82	mm
Stem Thickness	20	mm
umber	20 (22)	

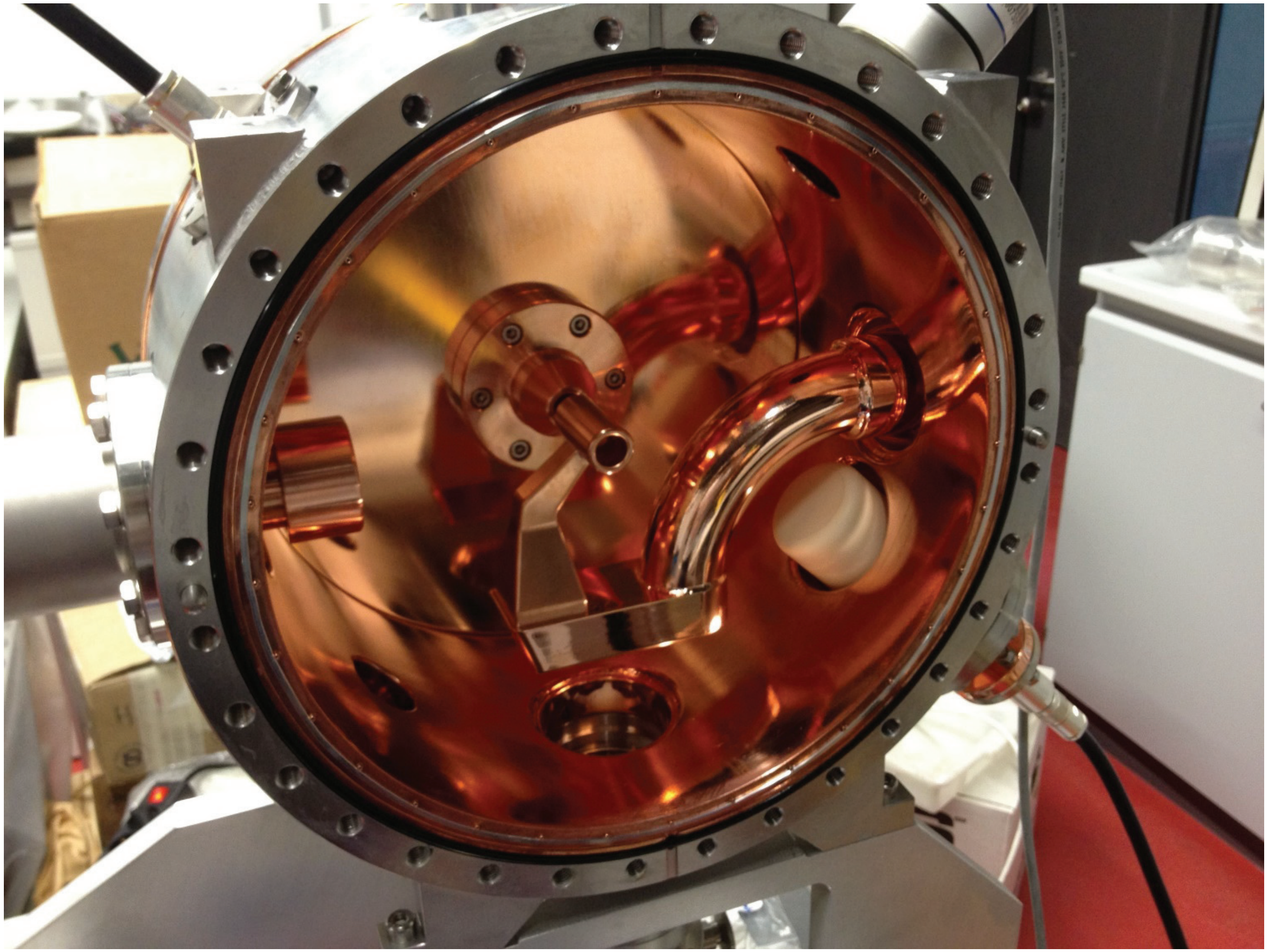


MEBT – Medium Energy Beam Transport

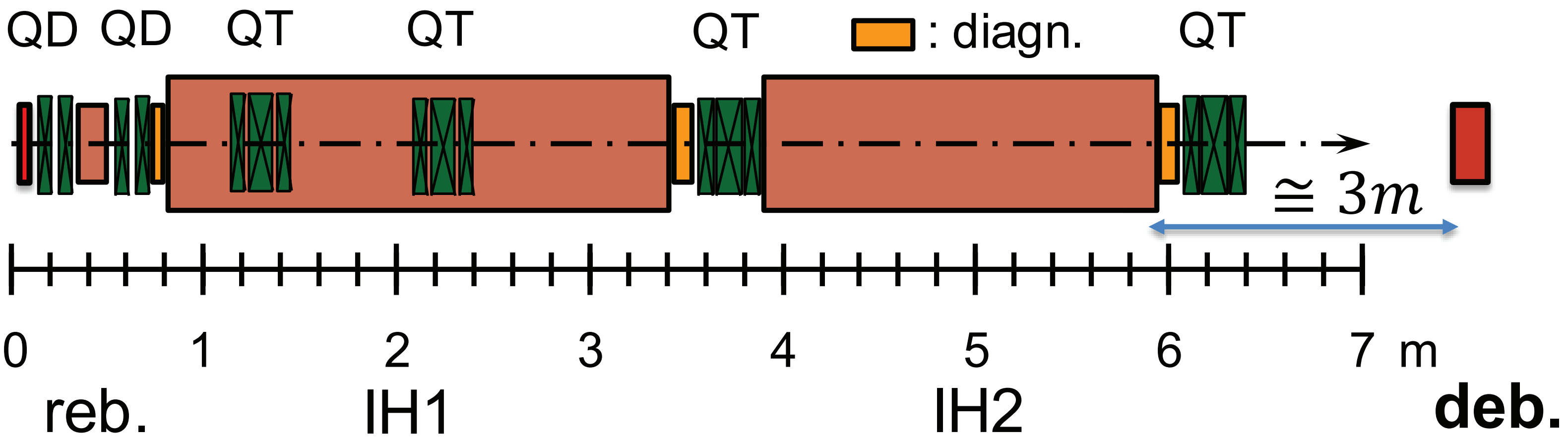


MEBT:
• 1 rebuncher cavity (2 gaps at -90 deg). • 2 quadrupole doublets. • 2 steerers. • Drift spaces reserved for diagnostic box(es) – 1 ACCT, 1 BPM

Spiral type design



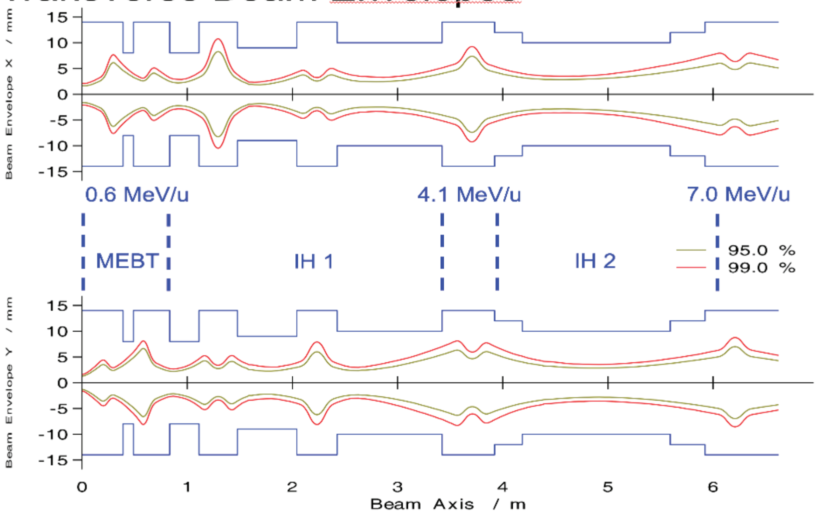
IH DTL



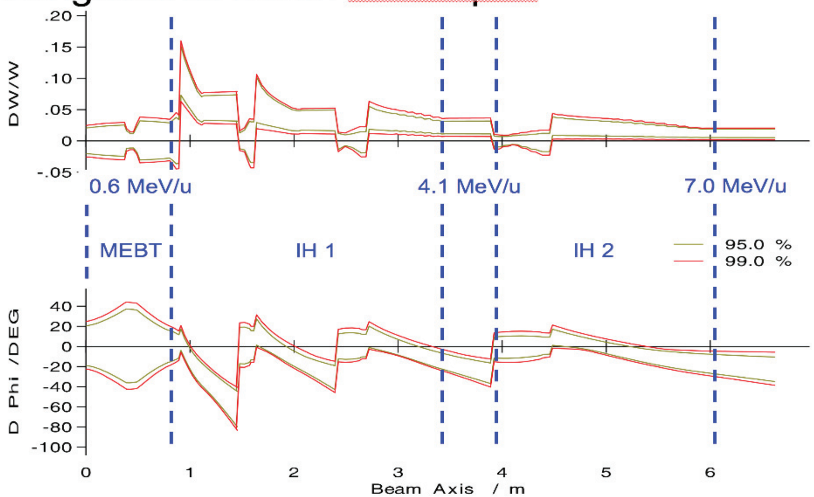
IH-DTL:
• IH1 with 2 internal quadrupole triplets, three drift tube sections, energy range 0.6 – 4.1 AMeV, total length ≈ 2.6 m. • IH2 with no internal lens, one drift tube section, energy range 4.1 – 7.0 AMeV, total length ≈ 2.0 m. • Two inter tank quadrupole triplets (between IH cavities and at exit). • BPM after each IH DTL and ACCT after IH 2

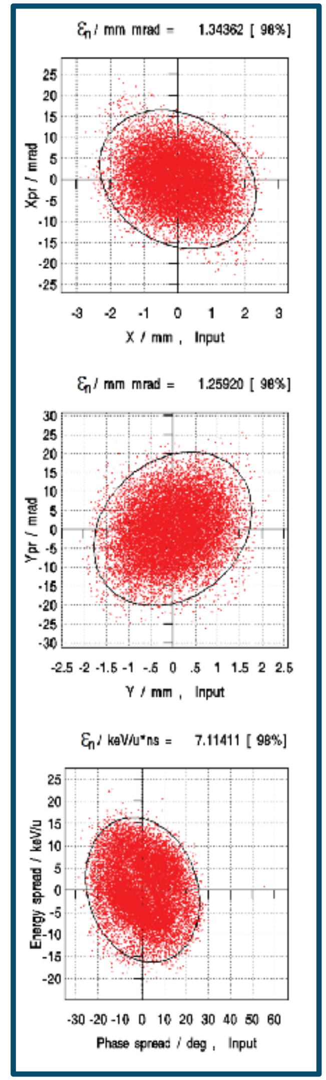
Design current 15mA @ A/Q=3

Transverse Beam Envelopes

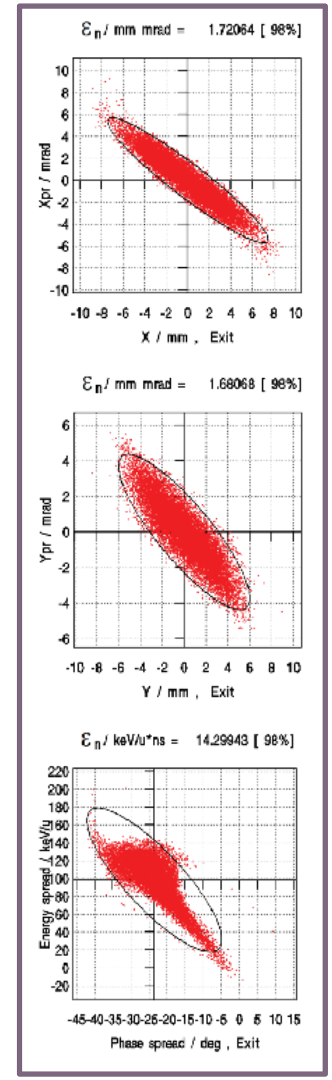


Longitudinal Beam Envelopes





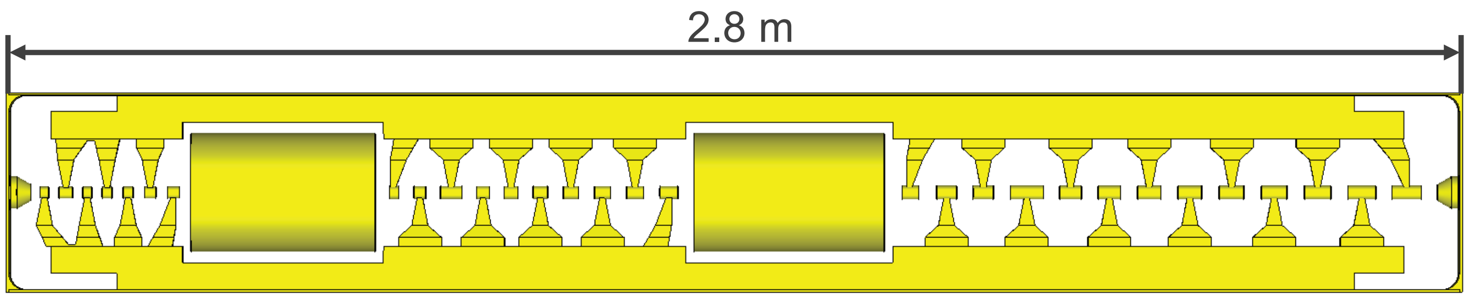
RFQ output



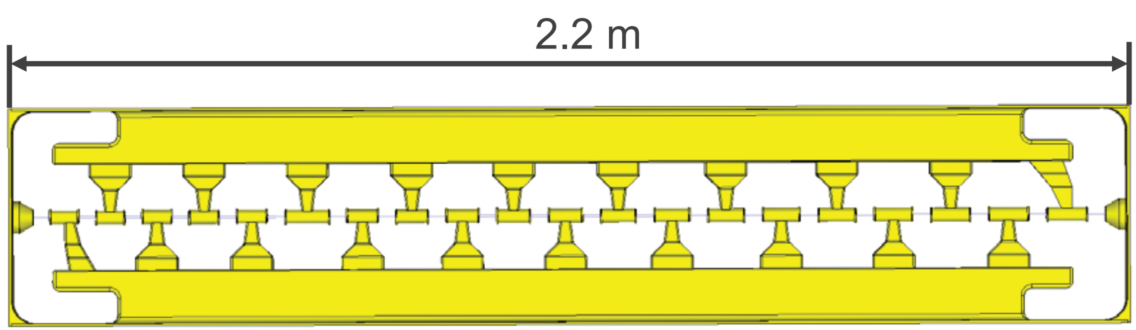
IH-DTL out|

LILac Cavities

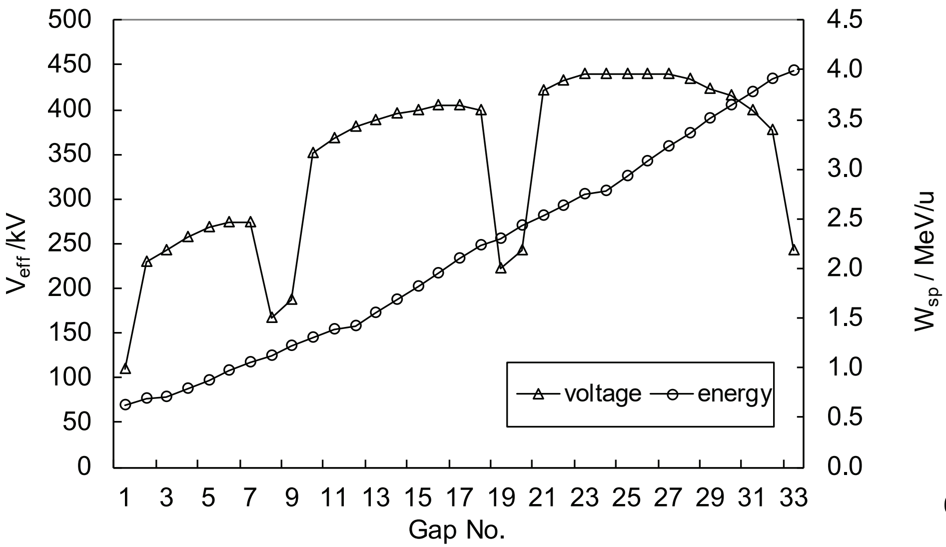
IH1
- 162.5 MHz
- 2.8 m length
- 0.5 m width & height
- 28 stems
- 2 internal lenses



IH2
- 162.5 MHz
- 2.2 m length
- 0.5 m width & height
- 20 stems

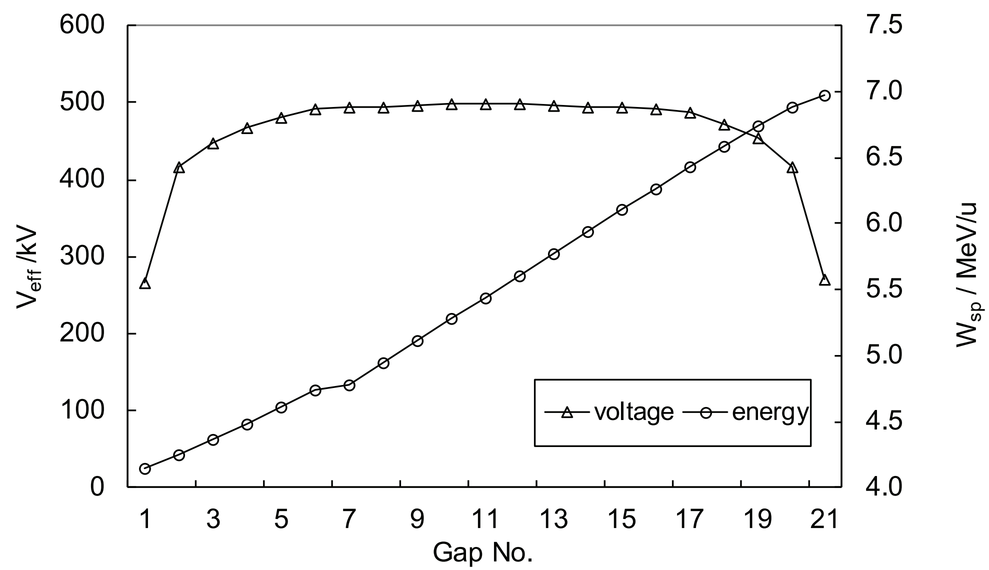


Gap Voltages and Energy Gain



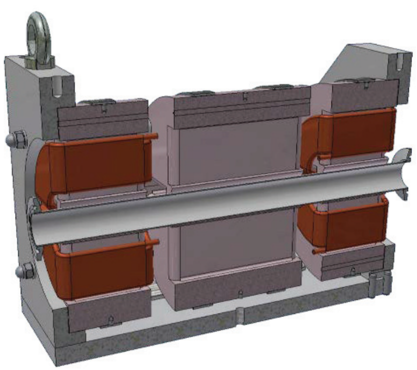
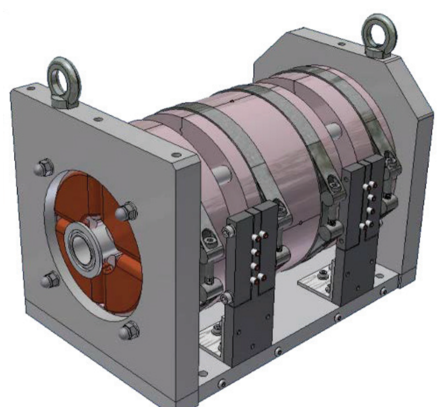
IH DTL 1

IH DTL 2

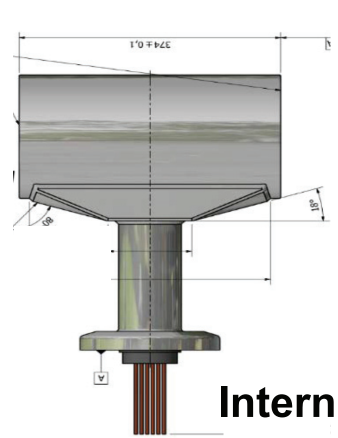
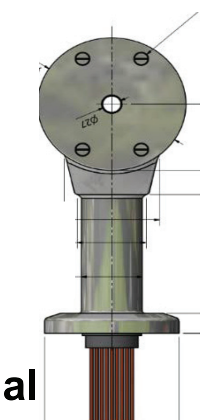
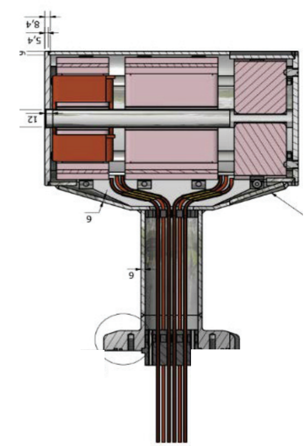


Quadrupole Triplets

Magnetic quadrupole doublet (QD)				
Effective pole length [mm]	59			
	QD1		QD2	
Magn. field gradient [T/m]	60.0; 62.5		60.0; 53.5	
Lens aperture diameter [mm]	28			
Magnetic quadrupole triplet (QT)				
Effective pole length [mm]	75 (outer singlets); 126 (central singlet)			
	QT1	QT2	QT3	QT4
Magn. field gradient [T/m]	52.2; 47.2; 52.2	57.5; 56.0; 57.5	51.0; 54.8; 51.0	49.0; 55.0; 49.0
Lens aperture diameter [mm]	28			

External

Internal

SSA for LILac (TRIADA TV)

Parameter	Value
Frequency	162.5 MHz
Banchwidth	$\pm$1.5 MHz
RF output power levels / Nr. of amplifiers in the proposal	10 kW / 2 amplifiers 250 kW / 1 amplifier 550 kW / 2 amplifier
RF pulse length	300 μs
Repetition rate	5 Hz
Beam pulse length	50 μs
Dury Cycle	0.15 %
Amplitude Linearity	<3 dB between 10 % and 90 % of max power
Phase Linearity	<2 ° between 10 % and 90 % of max power
Gain Stability over 24 h	< − 1.5 dB after 24 h operation
Amplitude Stability	<0.1 % over 1 s (open loop with matched load)
Pase Stability	<0.1 ° over 1 s (open loop with matched load)
Tilt	0.1 dB during last 50 μs
VSWR	Infinite any phase
RF input power	0 dBm, max
Harm. levels at ohmic load	< − 24 dBc
Non Harm. levels at ohmic load	< − 60 dBc
Max reflection	Full power with no circulator required
RF efficiency	>50 % DC to RF

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LLRF Hardware Platform

PICMG = PCI Industrial Computer Manufacturers Group

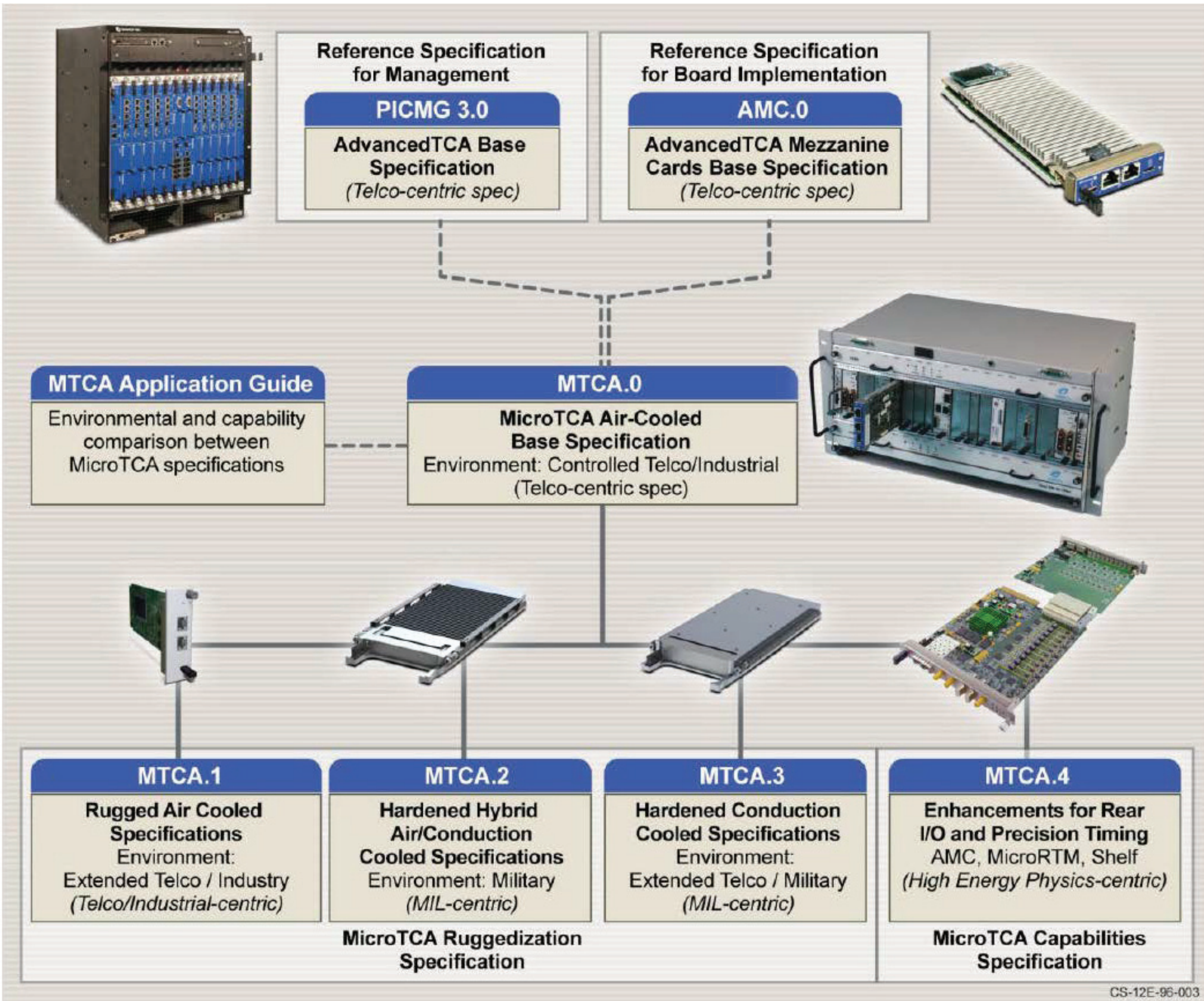

Figure 1. *The MicroTCA family of specifications maximizes reuse from its ATCA and AMC parent specifications.*

MTCA.4 = Micro Telecommunication Computing Architecture 4

Ref: MicroTCA App. Guide

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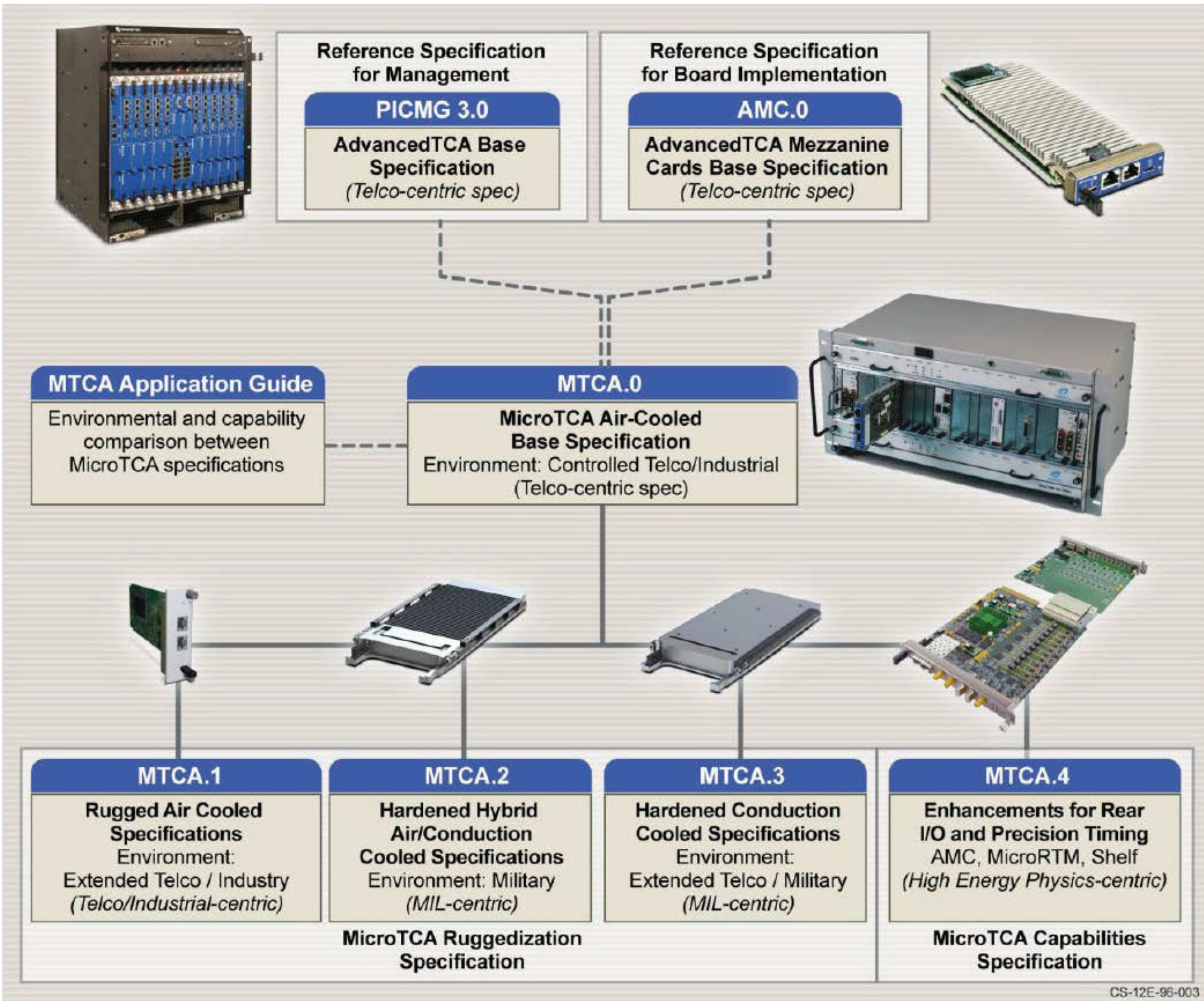

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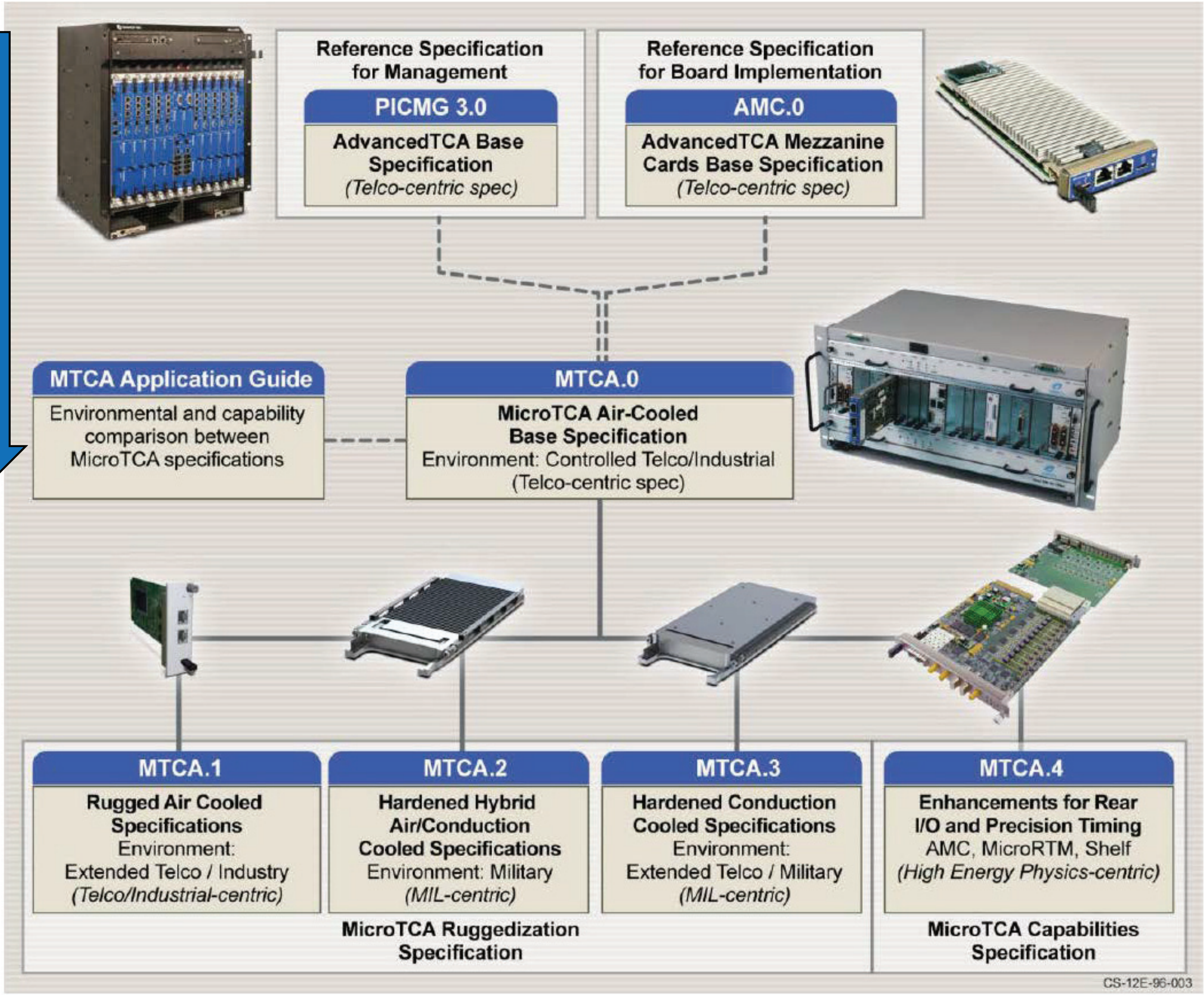

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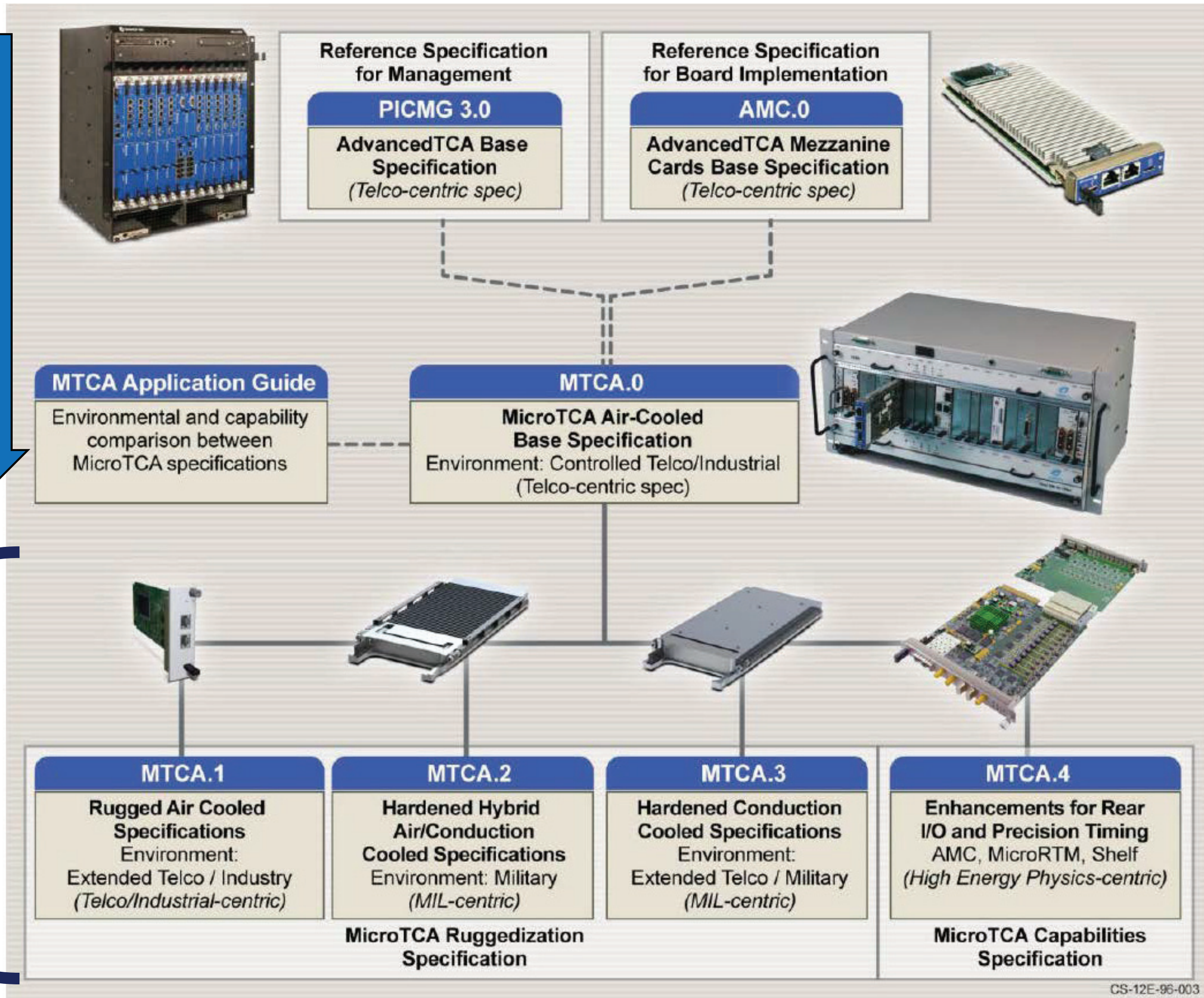

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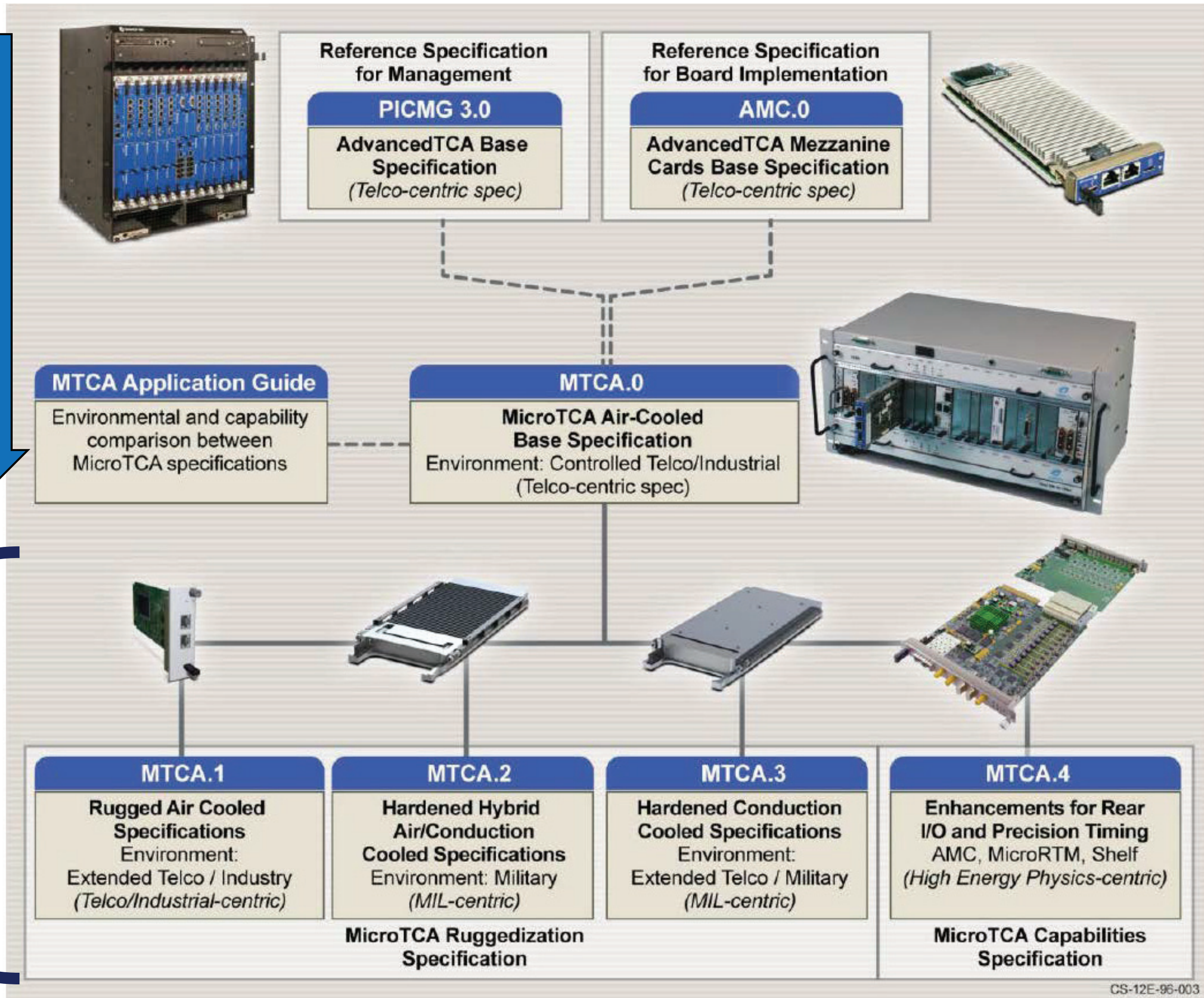
Mil. &Trans.



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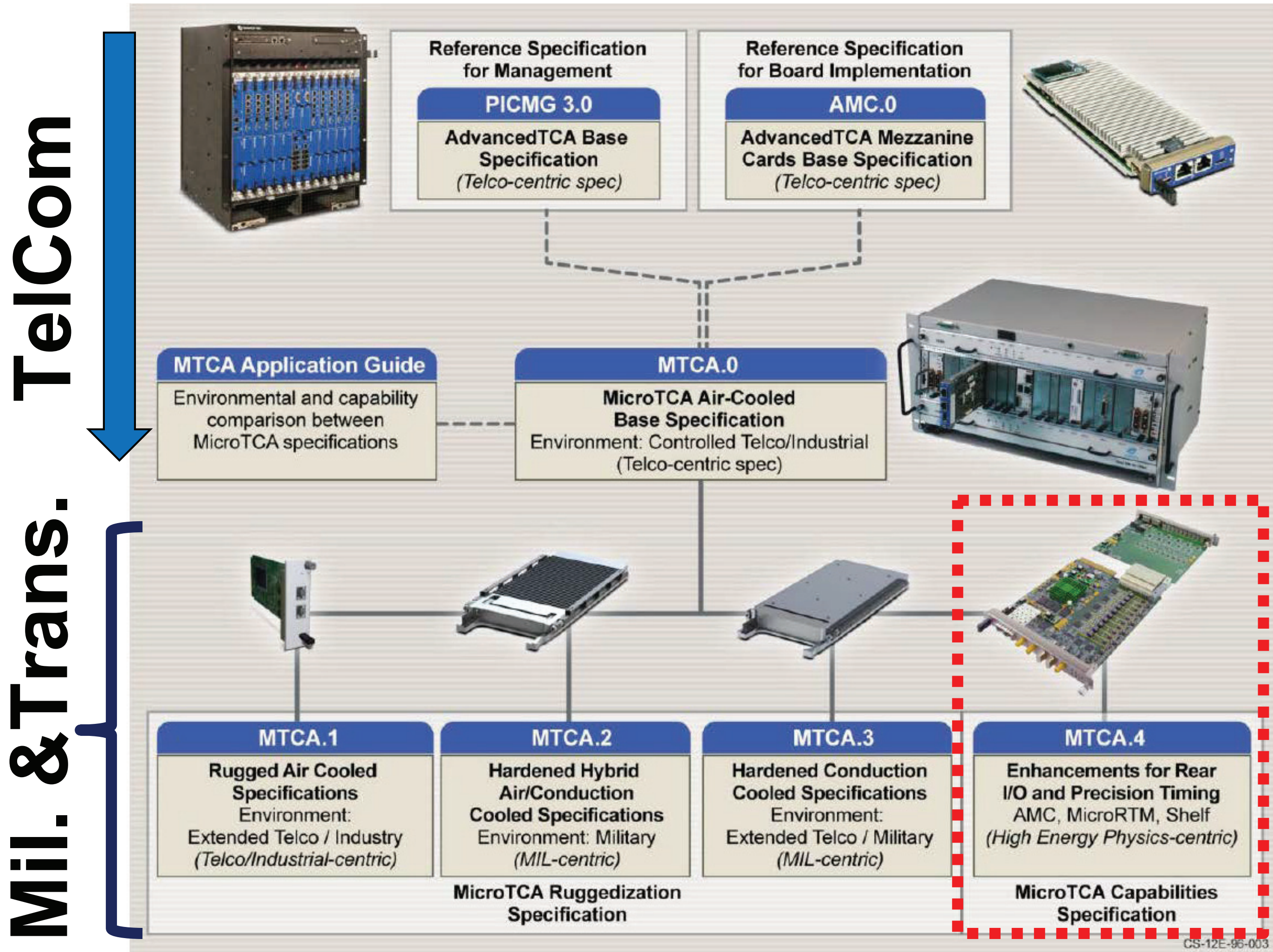

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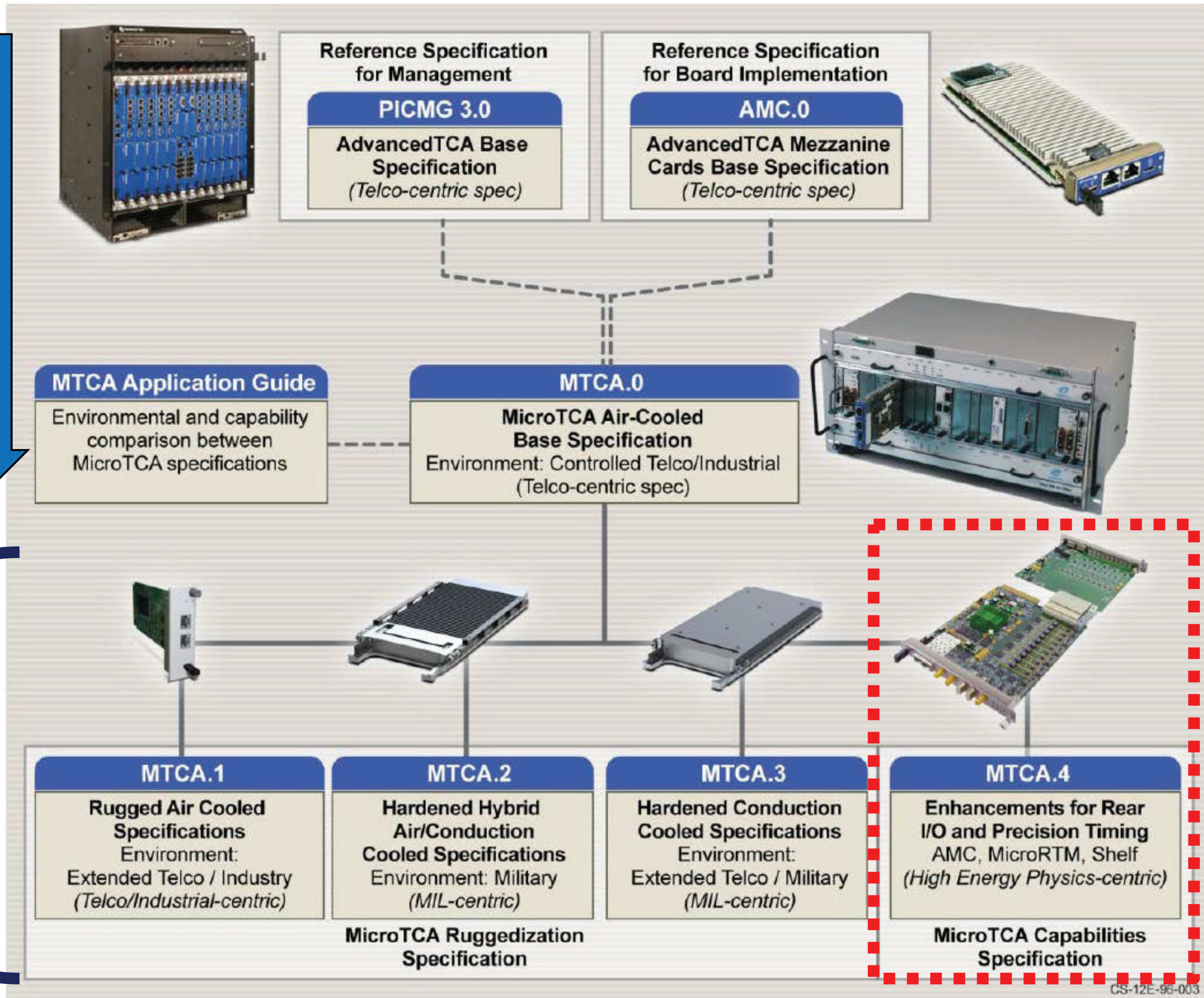

Science

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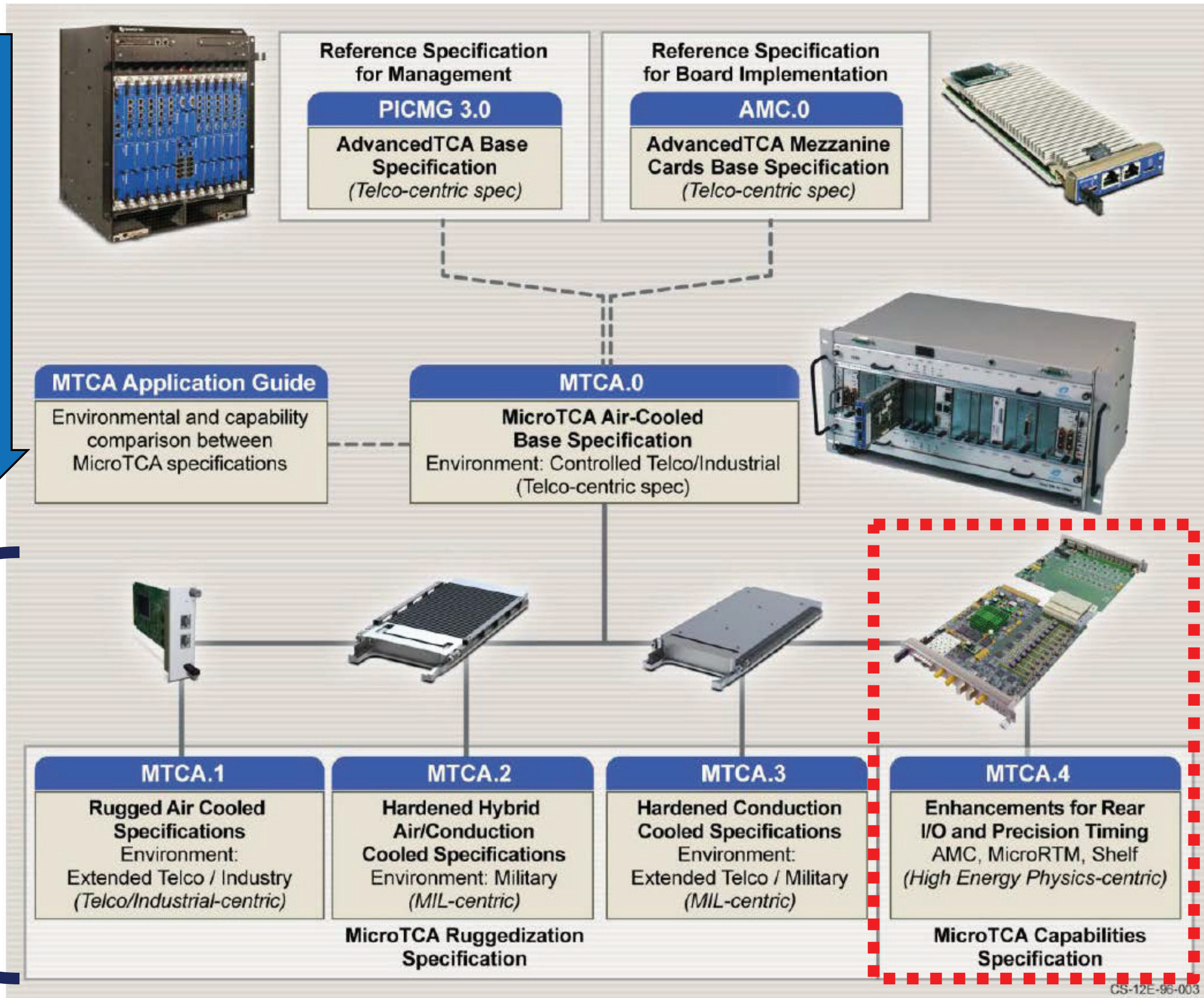

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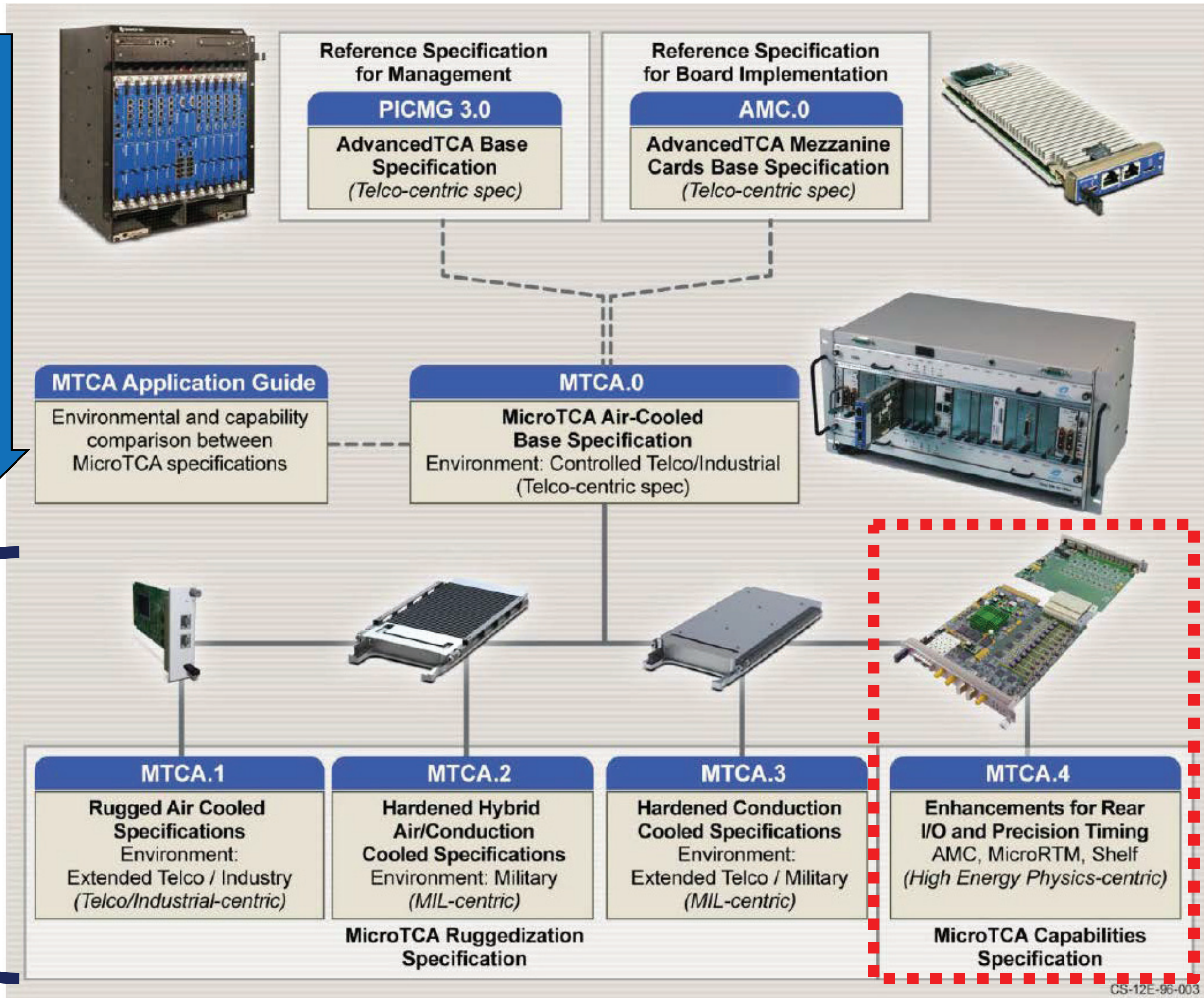

Science

MTCA.4 = Micro Telecommunication Computing Architecture 4

Establish in Science community

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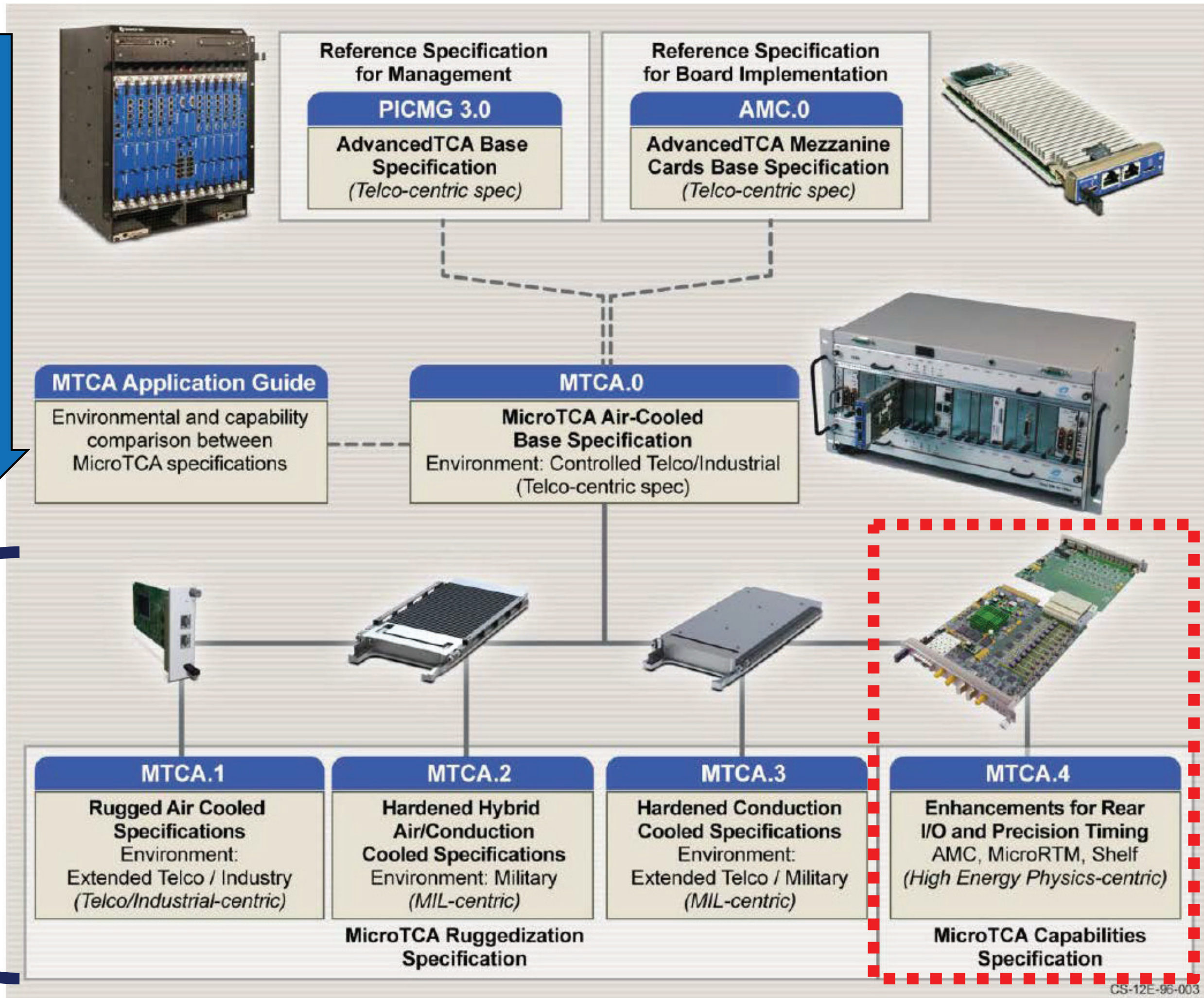

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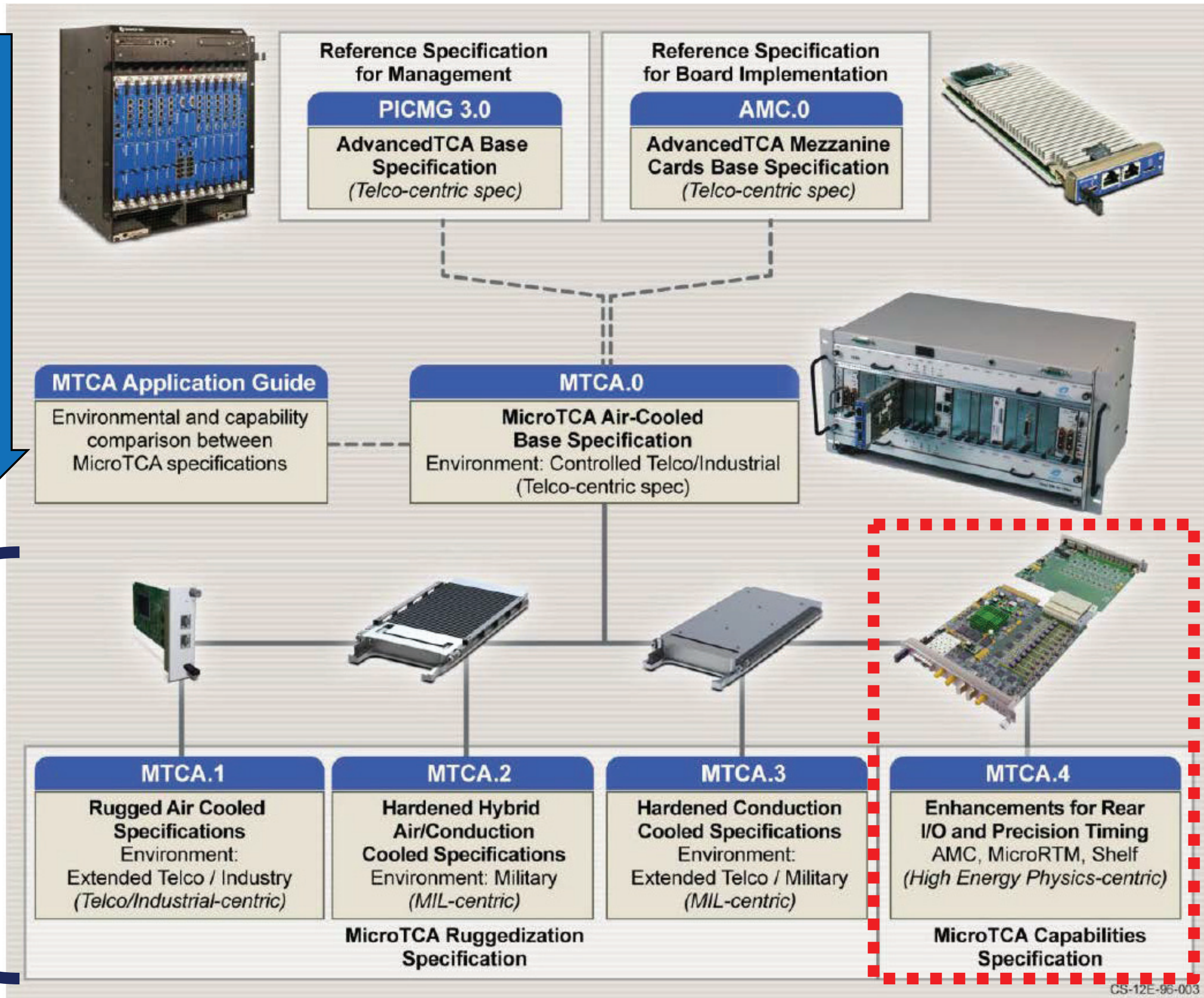

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Science

MTCA.4 = Micro Telecommunication Computing Architecture 4

Establish in Science community

Open new Industrial markets

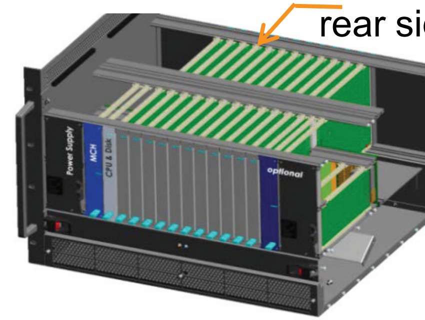
Ref: MicroTCA App. Guide

MTCA.4 Advantages

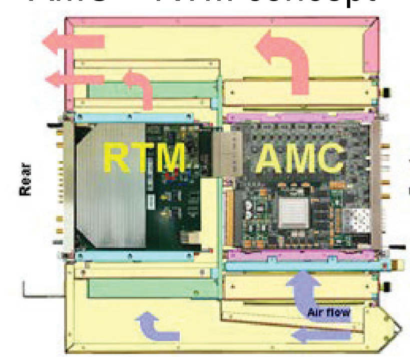
- **„xTCA for Physics“ interest group (38 partners): 03/2009**
  - **Research institutions: IHEP, SLAC, FNAL, IPFN, ITER, DESY, CERN, ESS**
  - **Industry: Connector-, Board-, Crate-, System vendors**
- **Modular & Modern architecture**
  - **Reusability + PCIe + Ethernet**
- **High reliability**
  - **Redundant Power Supply / Fans**
  - **Remote Maintenance through management**
- **High Performance**
  - **4x PCIe gen3 lane, 10GbE… 40 GBit/s**
  - **Low analog noise …**
- **Highly configurable / scalable**
  - **Small to large system**
  - **Different communication protocols / speed**

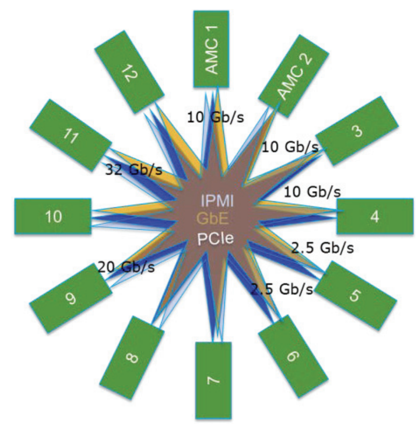
$$V = \frac{E[Uptime]}{E[Uptime] + E[Downtime]}$$

Cabling from rear side

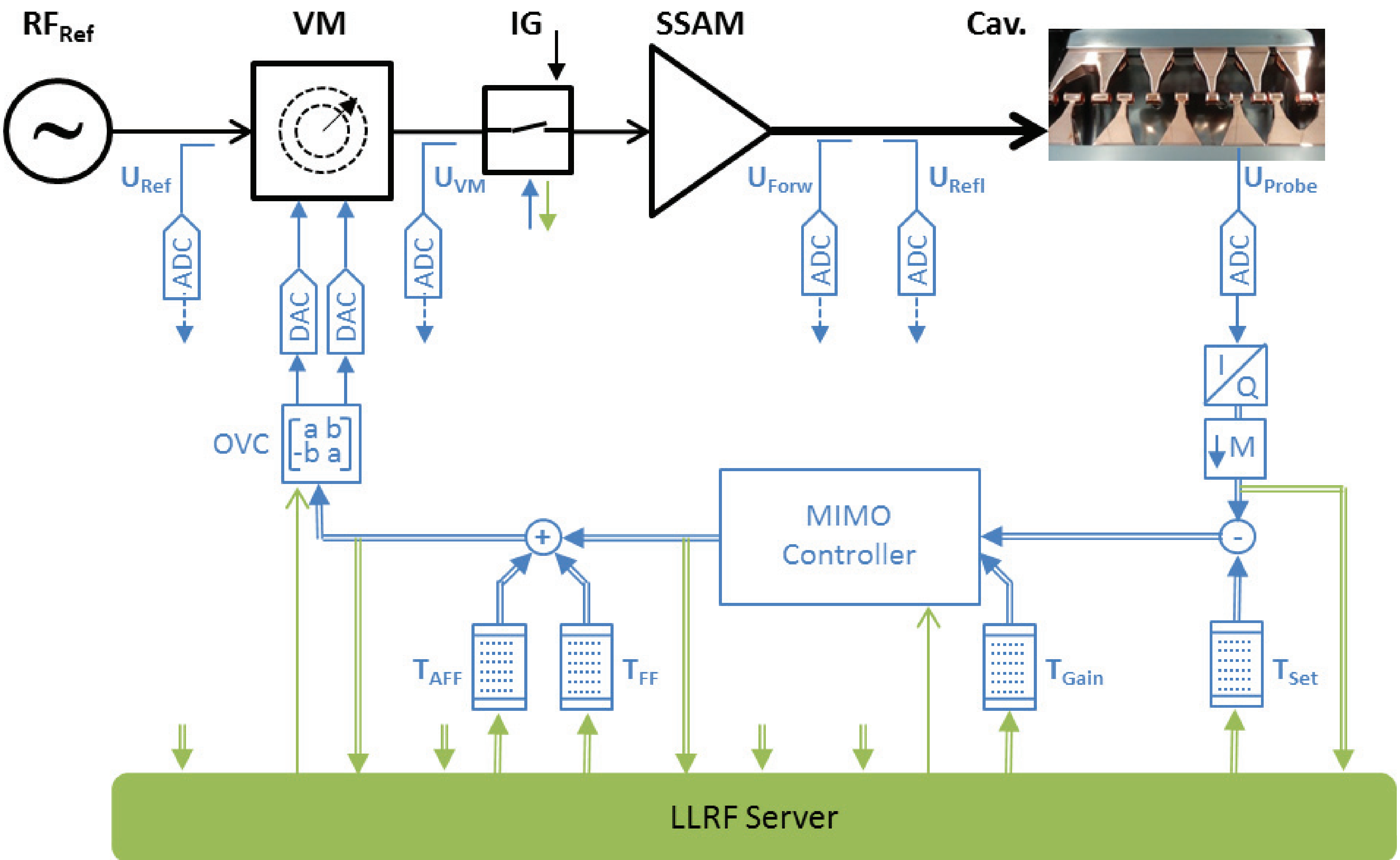


AMC – RTM concept





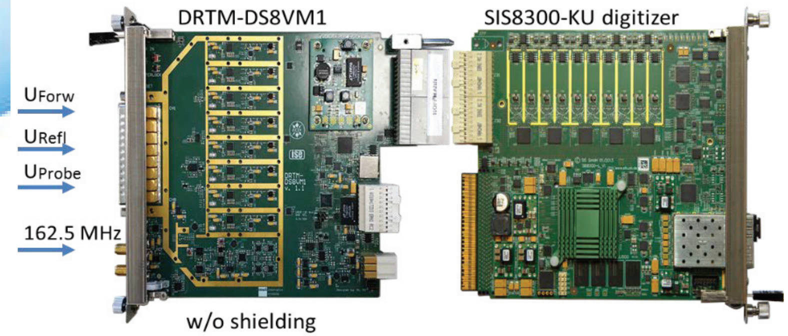
LLRF Scheme



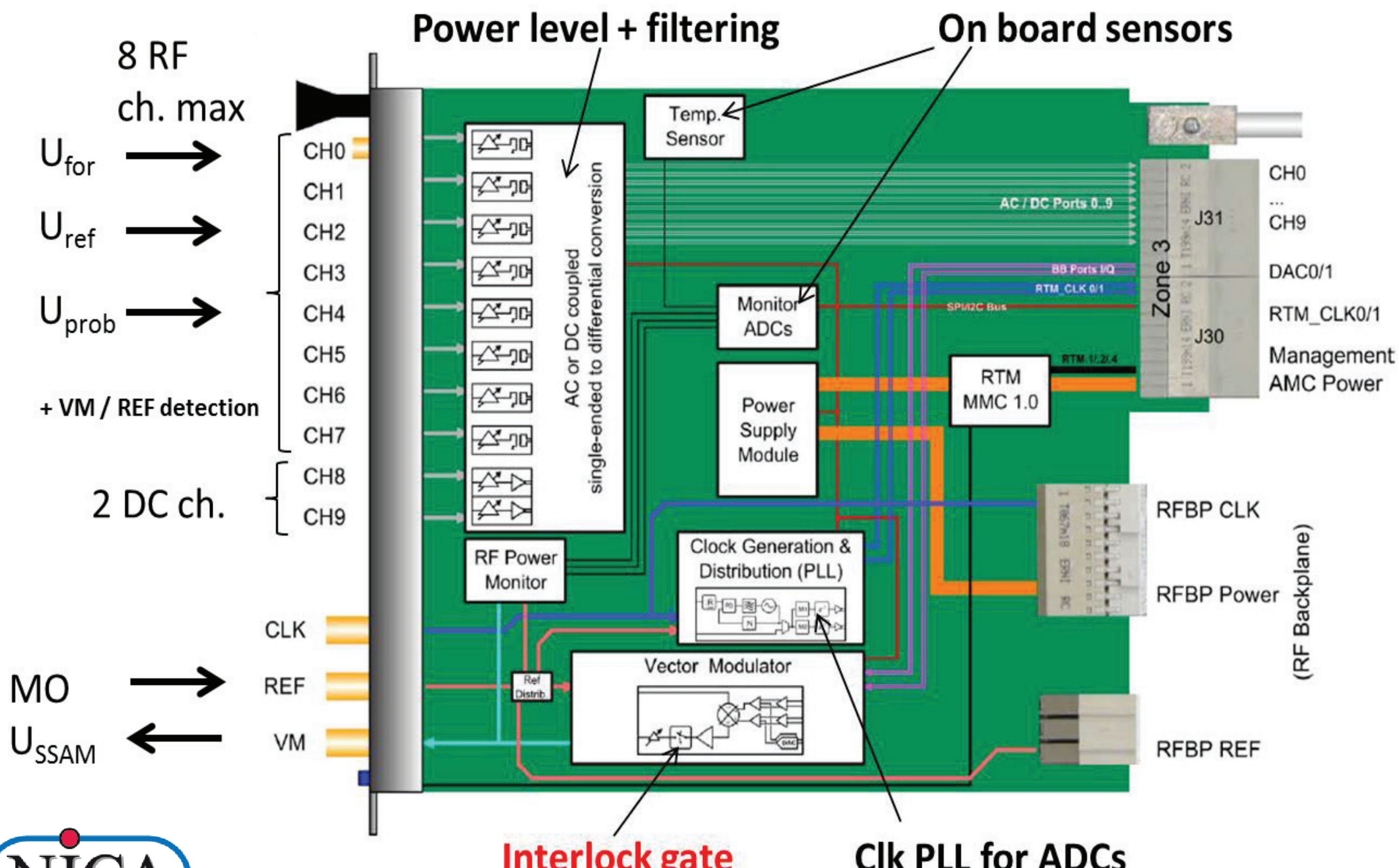
RF_{Ref}
VM
IG
SSAM
Cav.
U_{Ref}
U_{VM}
U_{Forw}
U_{Refl}
U_{Probe}
ADC
ADC
ADC
ADC
ADC
DAC
DAC
OVC
a b
-b a
I
Q
M
MIMO
Controller
+
-
T_{AFF}
T_{FF}
T_{Gain}
T_{Set}
LLRF Server

Cavity Connection

Adapted to 162,5 MHz

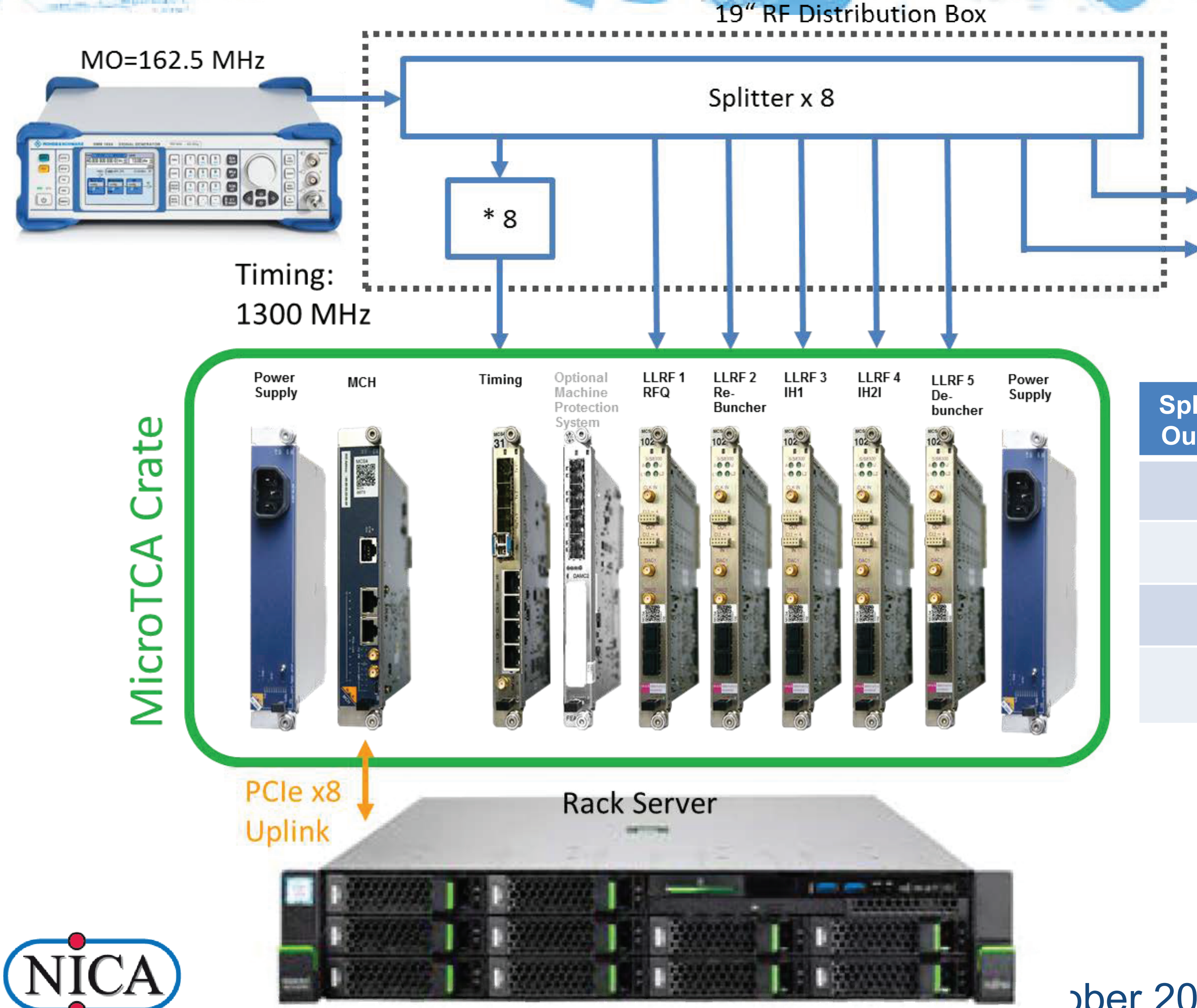


DRTM-DS8VM1 + SIS8300-KU Digitizer



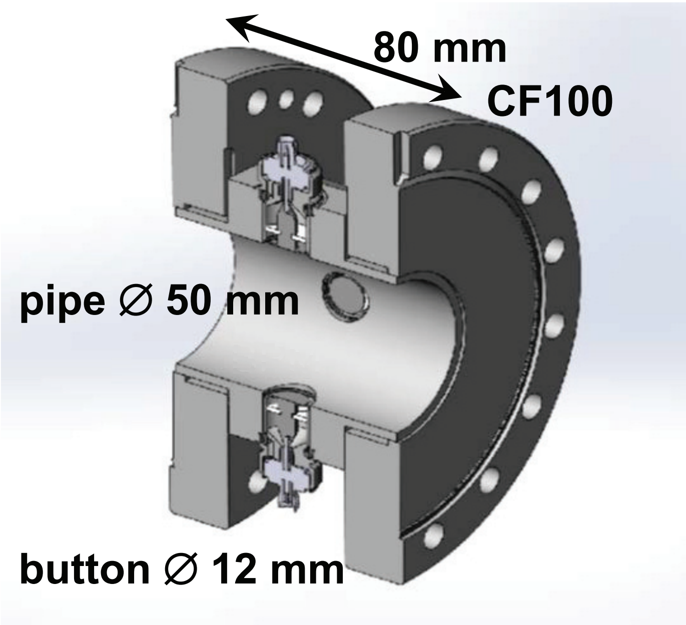
DRTM-DS8VM1

System Configuration

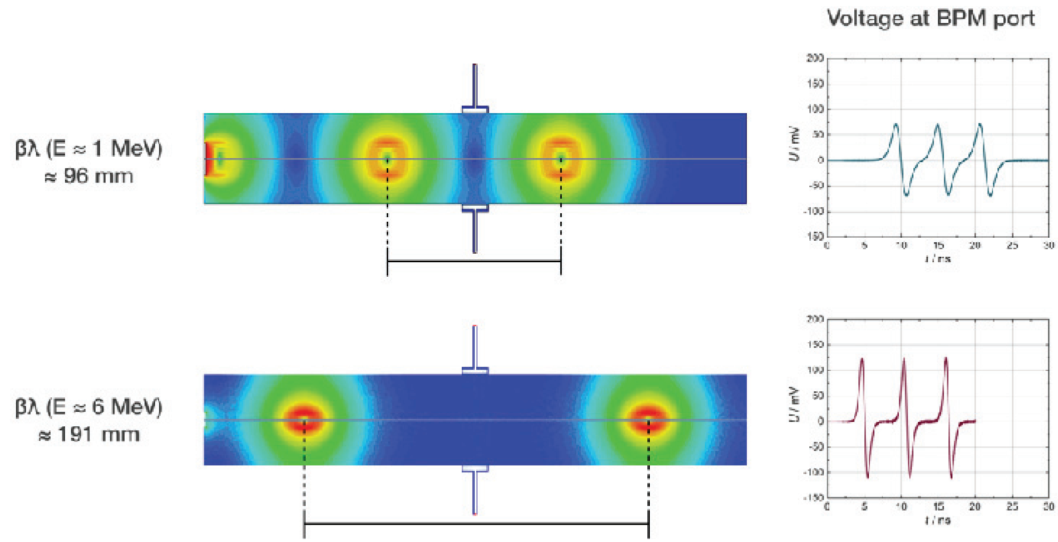


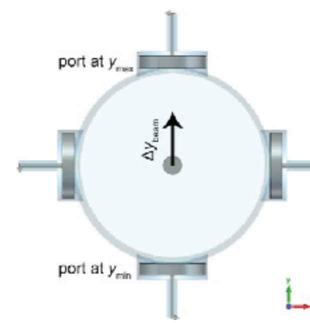
Splitter Output	Usage	Power Level
5	LLRF	15 dBm
1	Monitor	15 dBm
1	Spare	15 dBm
1	Timer (MO*8)	8 dBm

NICA – LILac Beam Diagnostics

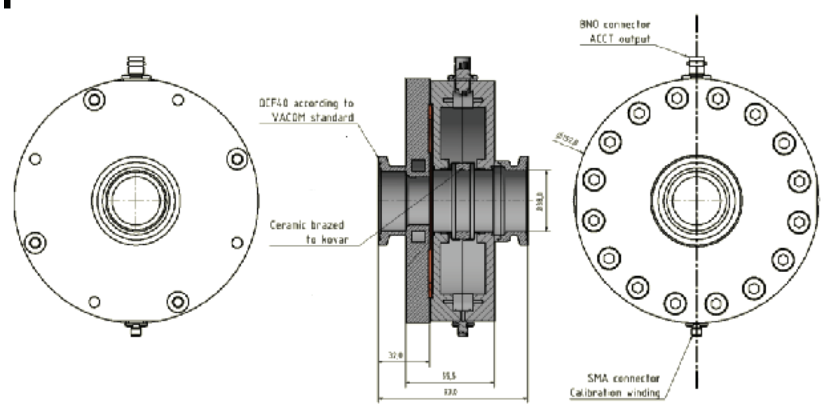


Source: P. Forck, GSI



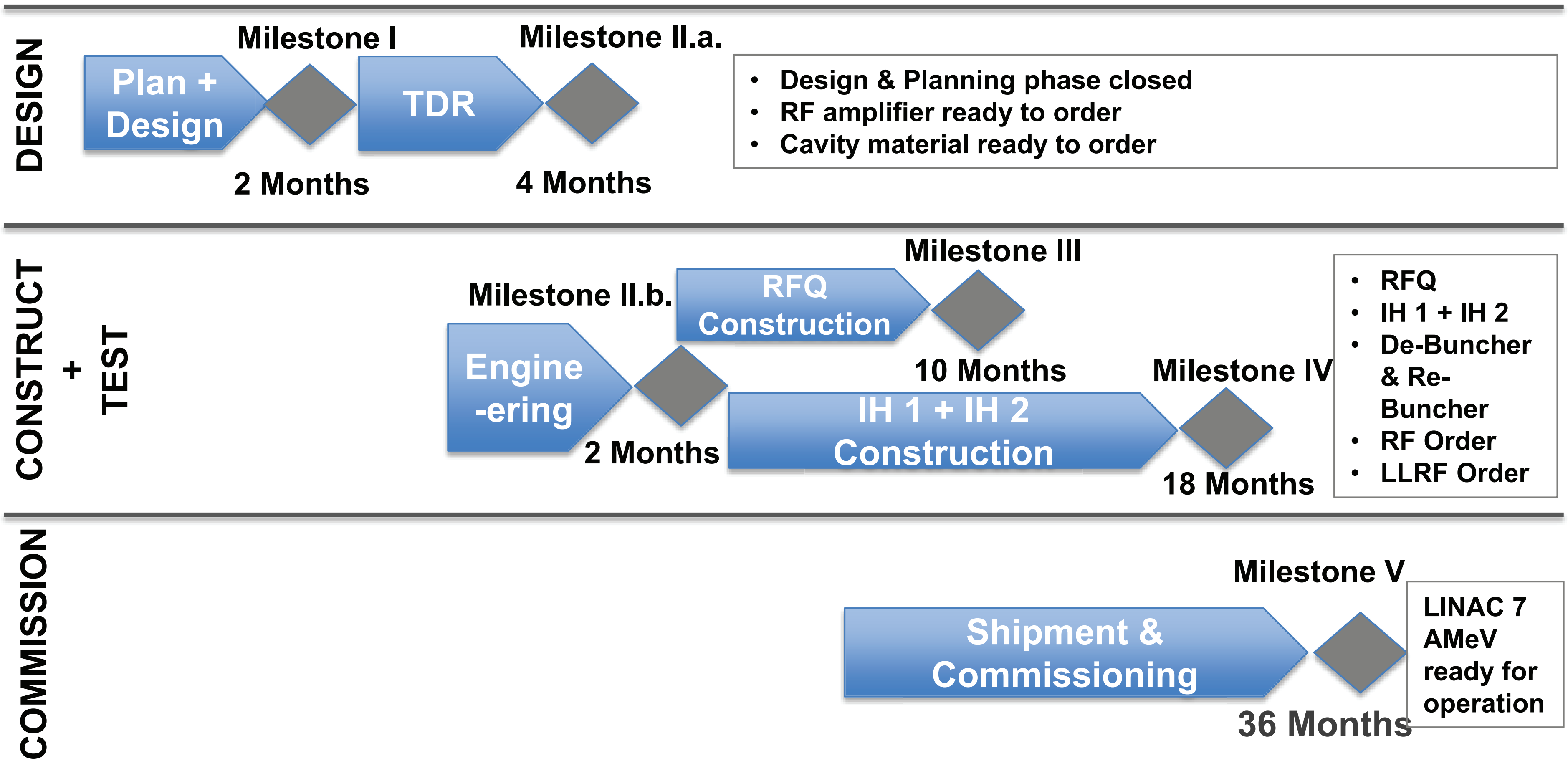


ACCT



Source: BERGOZ Instruments

High Level Project Schedule



Спасибо! Thank You! Vielen Dank!

LILAC 7 AMeV Workshop in April 2018