

Mechanical Design of Collimators and Manufacturing Strategy

**Review of the Cryogenic By-pass for
the LHC DS Collimators
26.05.2011**

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on behalf of the EN-MME Collimation Team
with inputs from many colleagues in EN, TE and BE departments

TCLD MECHANICAL DESIGN

COLLIMATOR MODULE (TCLD) LAYOUT

Collimator Module (TCLD)

Warm Module (VMGDA)

Collimator Support Assembly (HTC_)

Collimator Jack

Ion Pump (30 L/s)

Pirani Gauge

Penning Gauge

Ion Pump (30 L/s)

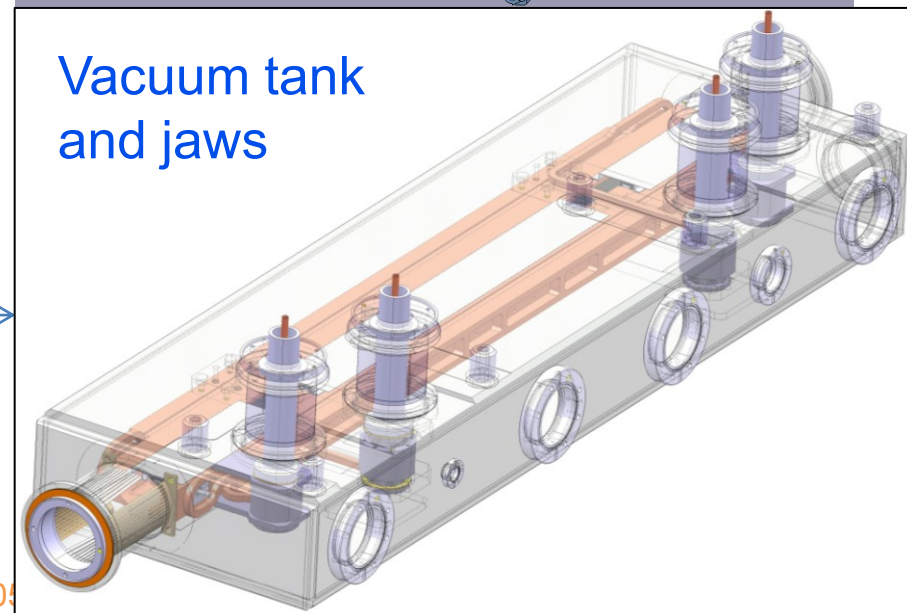
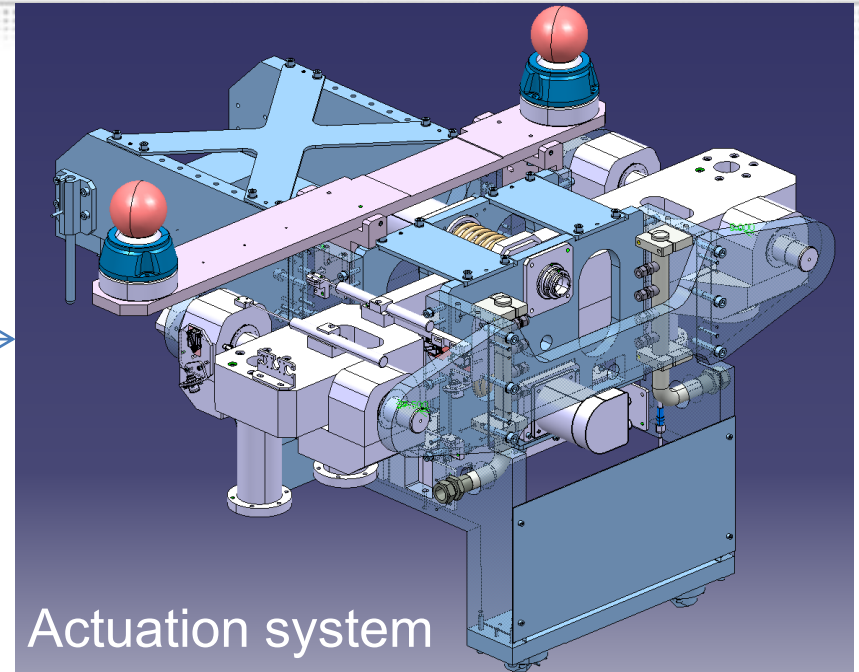
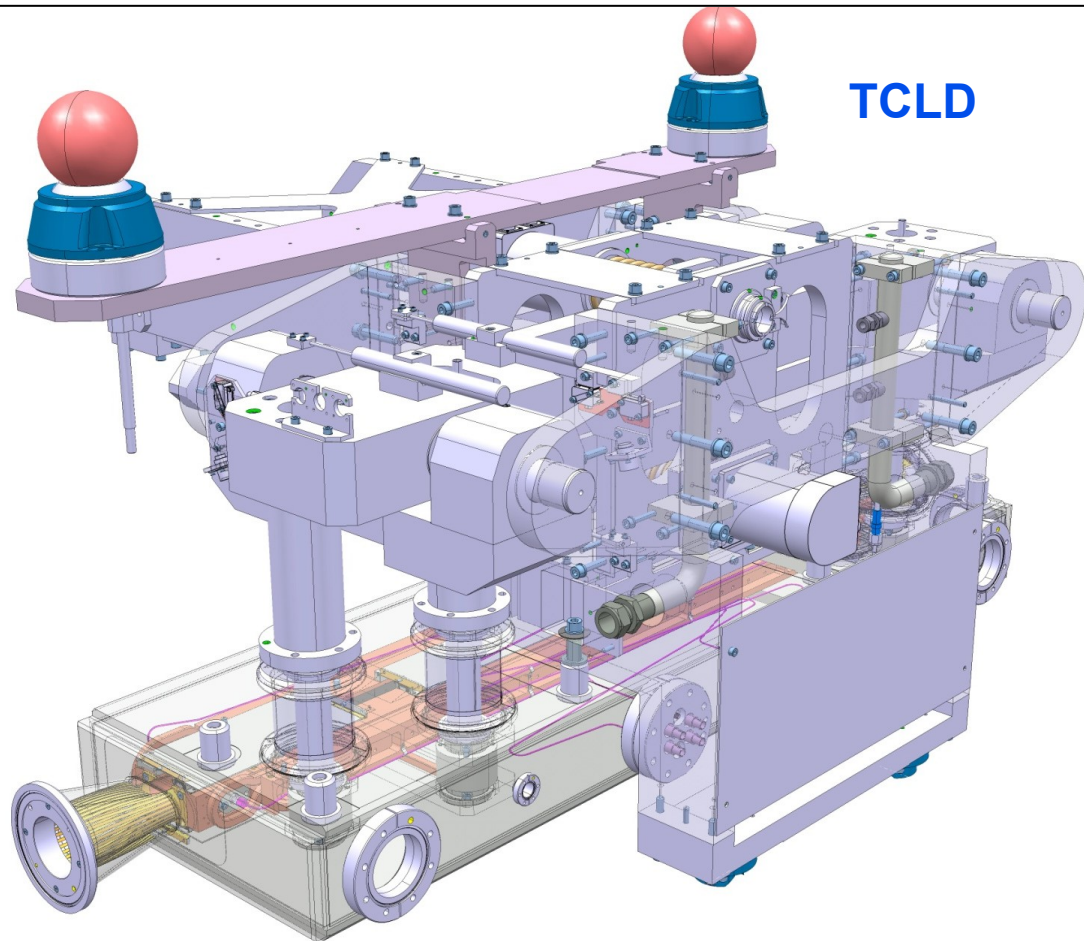
Angle valve

Mechanical Equipment

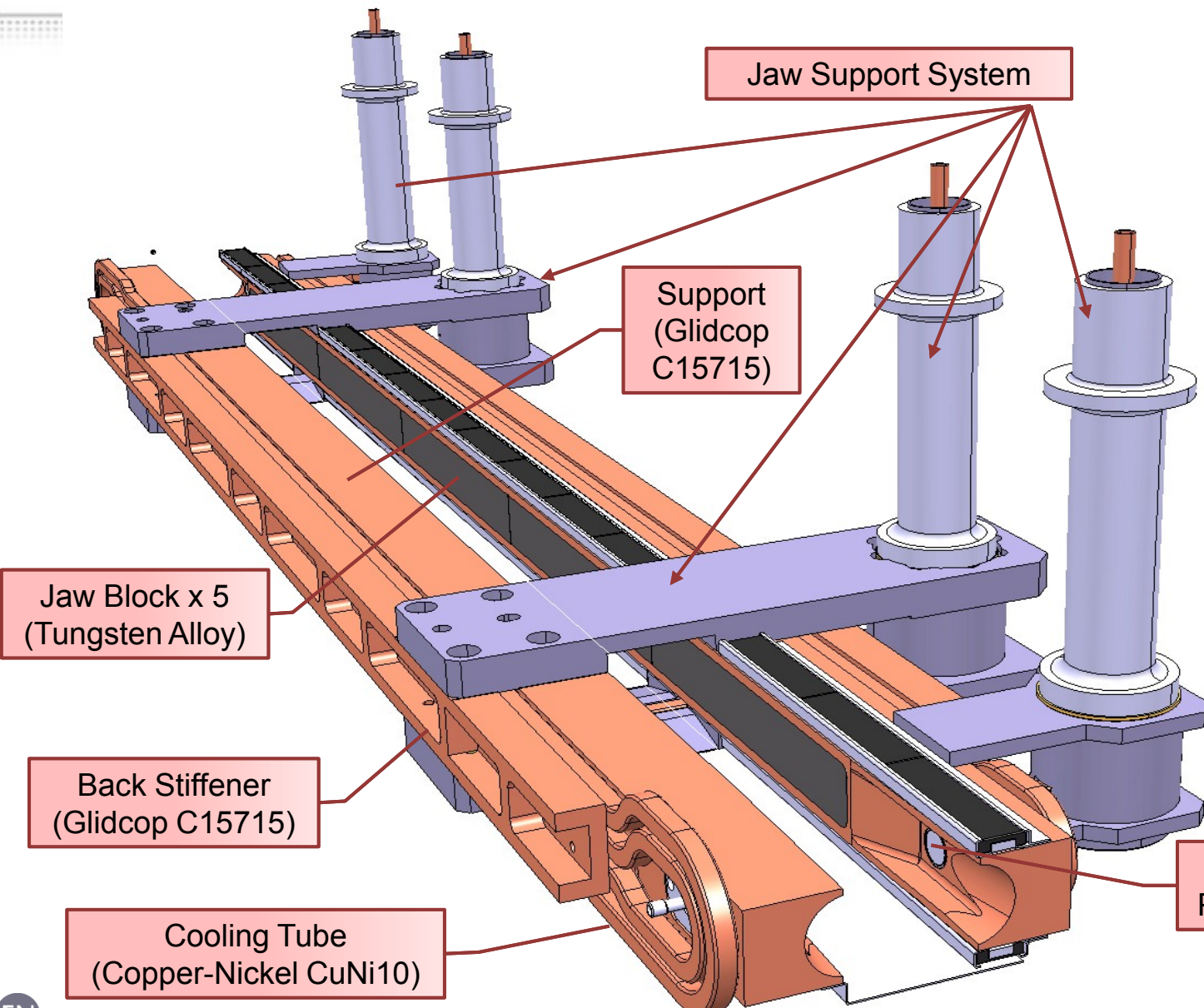
Vacuum Equipment

- Key Features**
- TCLD fully independent from QTC
 - Specific support and jacks for TCLD.
 - Horizontal Orientation
 - Hydraulic and electrical manual connections

TCLD PRODUCT BREAKDOWN



TCLD JAW DESIGN (1/2)



Jaw Support System

Support
(Glidcop
C15715)

Jaw Block x 5
(Tungsten Alloy)

Back Stiffener
(Glidcop C15715)

Cooling Tube
(Copper-Nickel CuNi10)

BPM
Pick-up buttons

- ### Key Features
- Total length: 1200 mm (including 100m tapering)
 - Active length: 1000 mm (5 blocs x 200 mm)
 - Asymmetric jaw supporting system
 - Continuous cooling circuit
 - Contactless RF shielding
 - BPM pickups: 2 per jaw
 - Temperature Diagnostics (2 PT100 per jaw)

TCLD JAW DESIGN (2/2)

Jaw assembling principles

Brittle W block contained by Glidcop support

Key Features

- Block width: 20 mm
- Block height: 30 mm
- Bloc material: 95%W+3.5%Ni+1.5%Cu (Inermet IT180)
- Water Flow rate: ≤ 5 L/min (3 m/s)
- Water Inlet Pressure 9 ÷ 16 bar
- Test pressure 50 bar

40mm

Vacuum Brazing between Support, Pipe and Stiffener

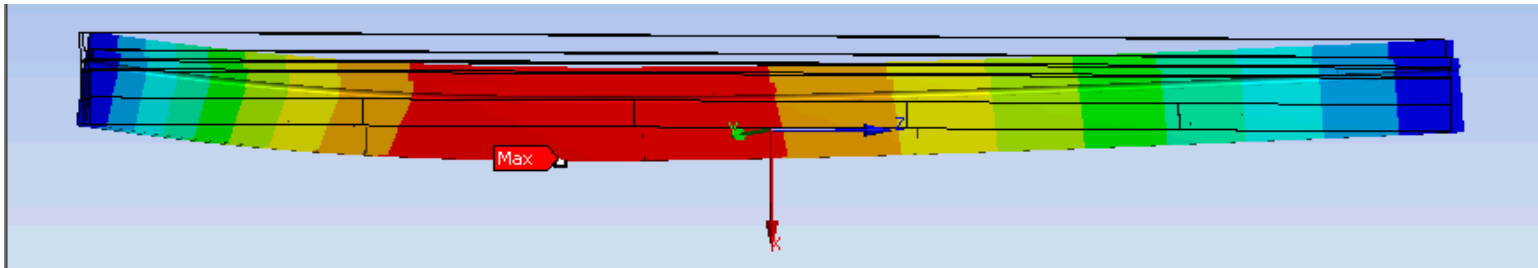
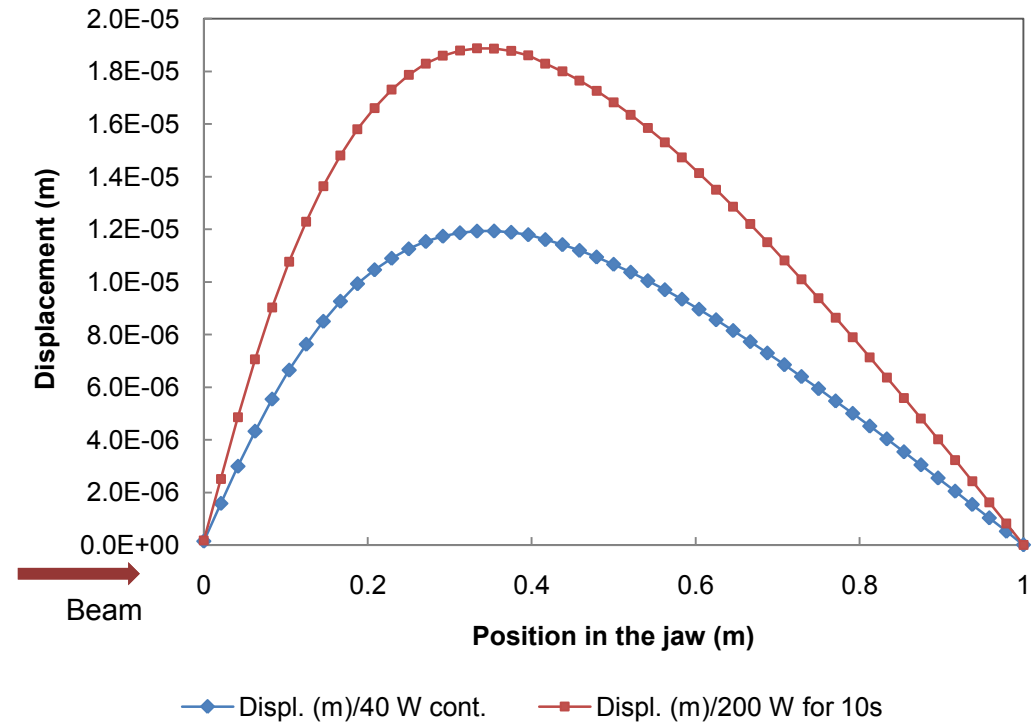
Free pressed contact between W and Glidcop (15 bar pressure)

Contact between W and Glidcop ensure by A4 St. Steel Screw

75mm

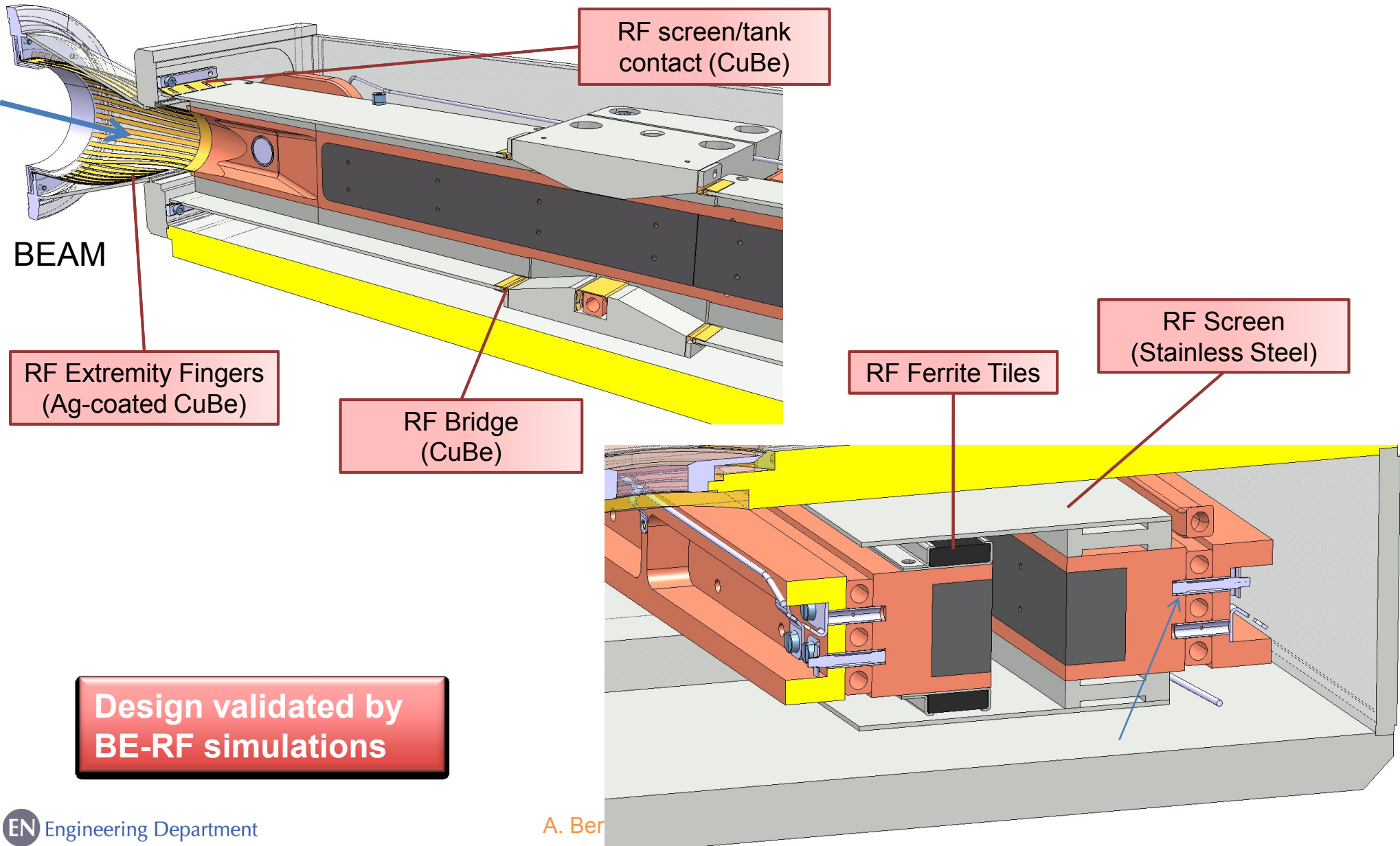
- **Specified Heat Loads**
 - 40 W (Steady-state – 1 hr Beam Lifetime)
 - 200 W (10 s transient – 0.2 hr Beam Lifetime)
- **Specified max Thermal Deflection**
 - 50 μm (Steady-state)
- **Expected thermal deflection**
 - 12 μm (Steady-state)
 - 20 μm (10 s transient)

factor 4





RF CONFIGURATION FOR TCLD



BEAM

RF Extremity Fingers (Ag-coated CuBe)

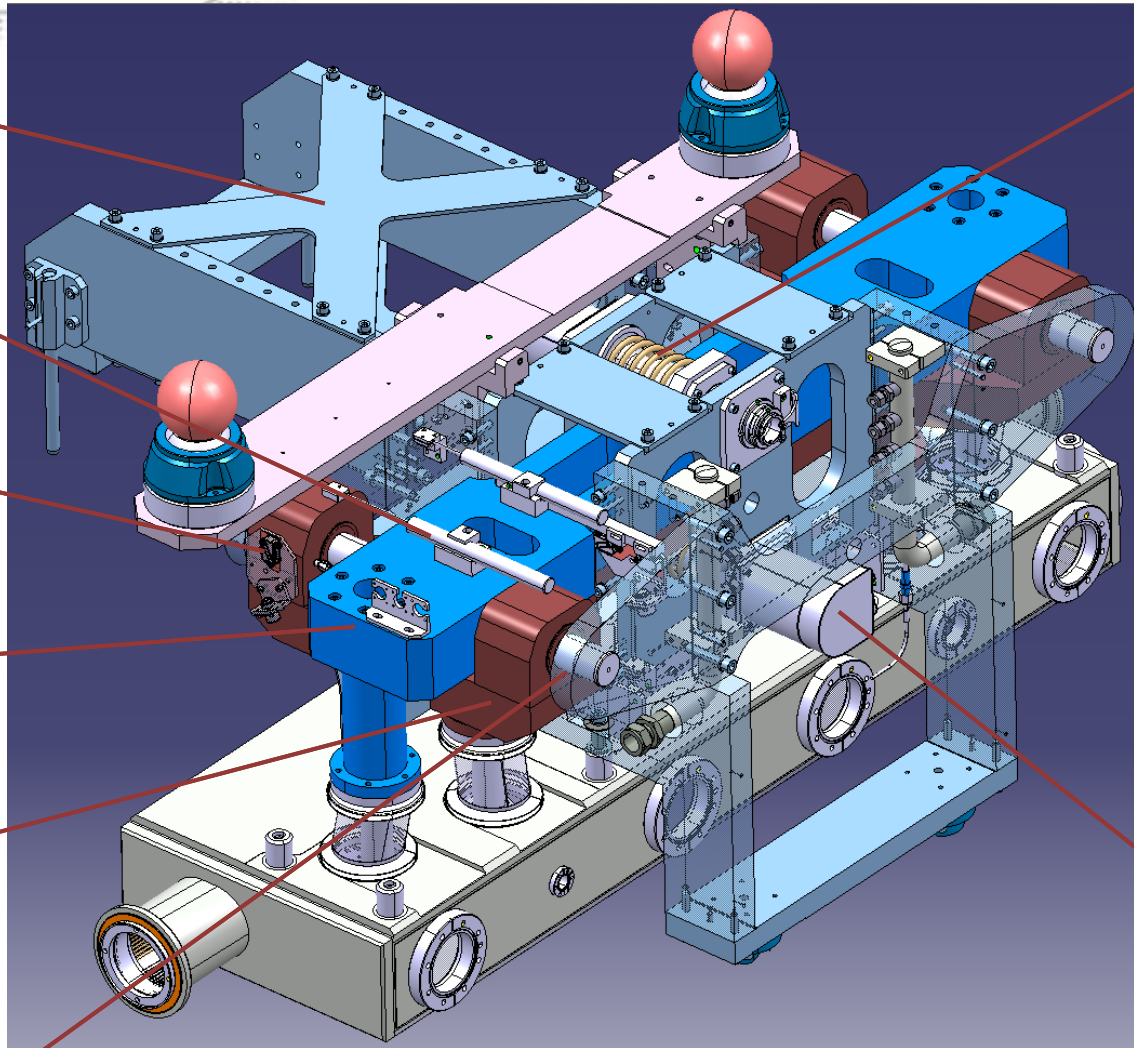
RF Bridge (CuBe)

RF Ferrite Tiles

RF Screen (Stainless Steel)

Design validated by BE-RF simulations

ACTUATION SYSTEM



Support Frame
(AI 6082)

Stroke LVDT x 3

Stroke switch x 5

Sliding Table 1
(AI 6082)

Sliding Table 2
(AI 6082)

Linear Bearing and Shaft
X 2

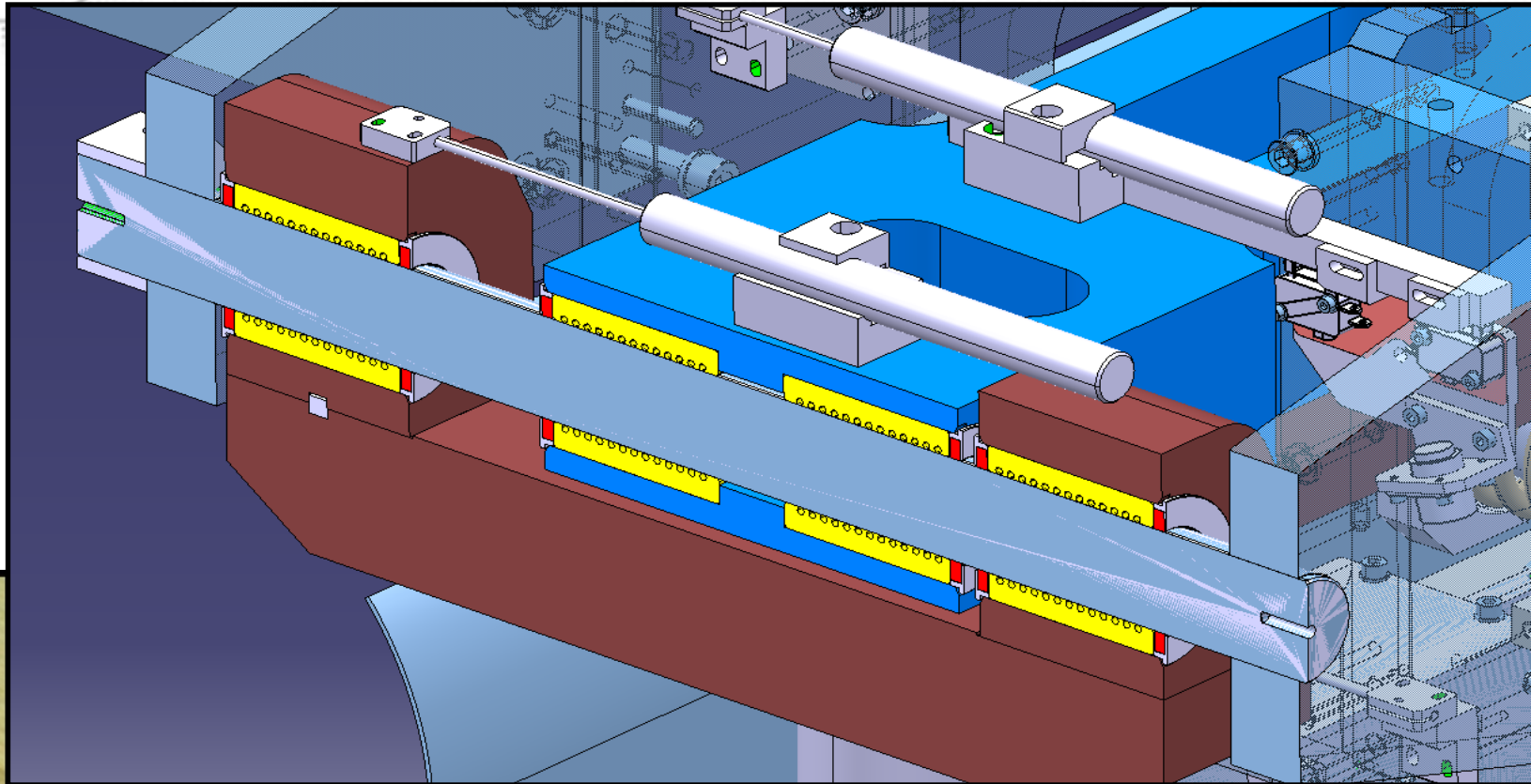
Return Spring
X 2

- Key Features**
- 1 D.o.F per jaw (1 motor, no angular adjustment)
 - Jaw stroke: 25 mm
 - Jaw auto-retraction up to ~ 170 mNm (no auto-retraction in case of motor short-circuit)
 - Phase 1 Stepping Motors and Electronics

Stepping Motor
X 2

ACTUATION SYSTEM

- All-metal sealed Linear Ball Bearings
- Graphite Dry Film Lubricated (DAG 156)
- Graphite Sealing Ring

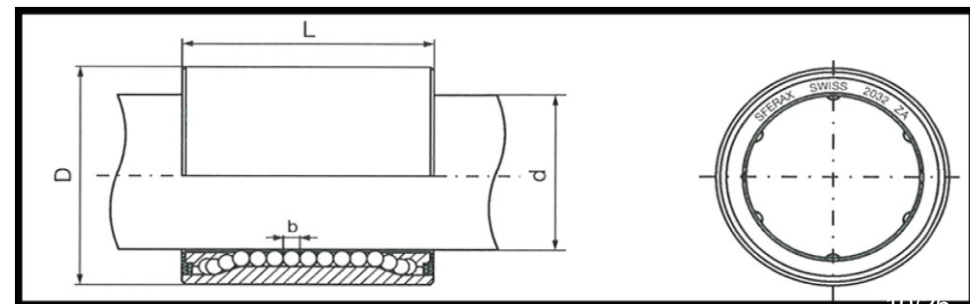


SFERAX 4060

Dim.= D60; d40; L72 mm

Stainless steel

(tested on Phase 2 Table for 30000 cycles)



MANUFACTURING STRATEGY

1. **DS Collimators for IR3 (LTC) – 5 units**

- Engineering & Design
- Manufacturing and assembly of 5 units (QTC+TCLD)

**Object of
this review**



2. **Phase 1 collimators for IR3 (Phase 1+) – 7 units.**

- Design update.
- Manufacturing of 1 Primary Collimator (TCP)
- Procurement of raw material and strategic components.

3. **TCTP (Tertiary Collimators with BPMs) – 18 units.**

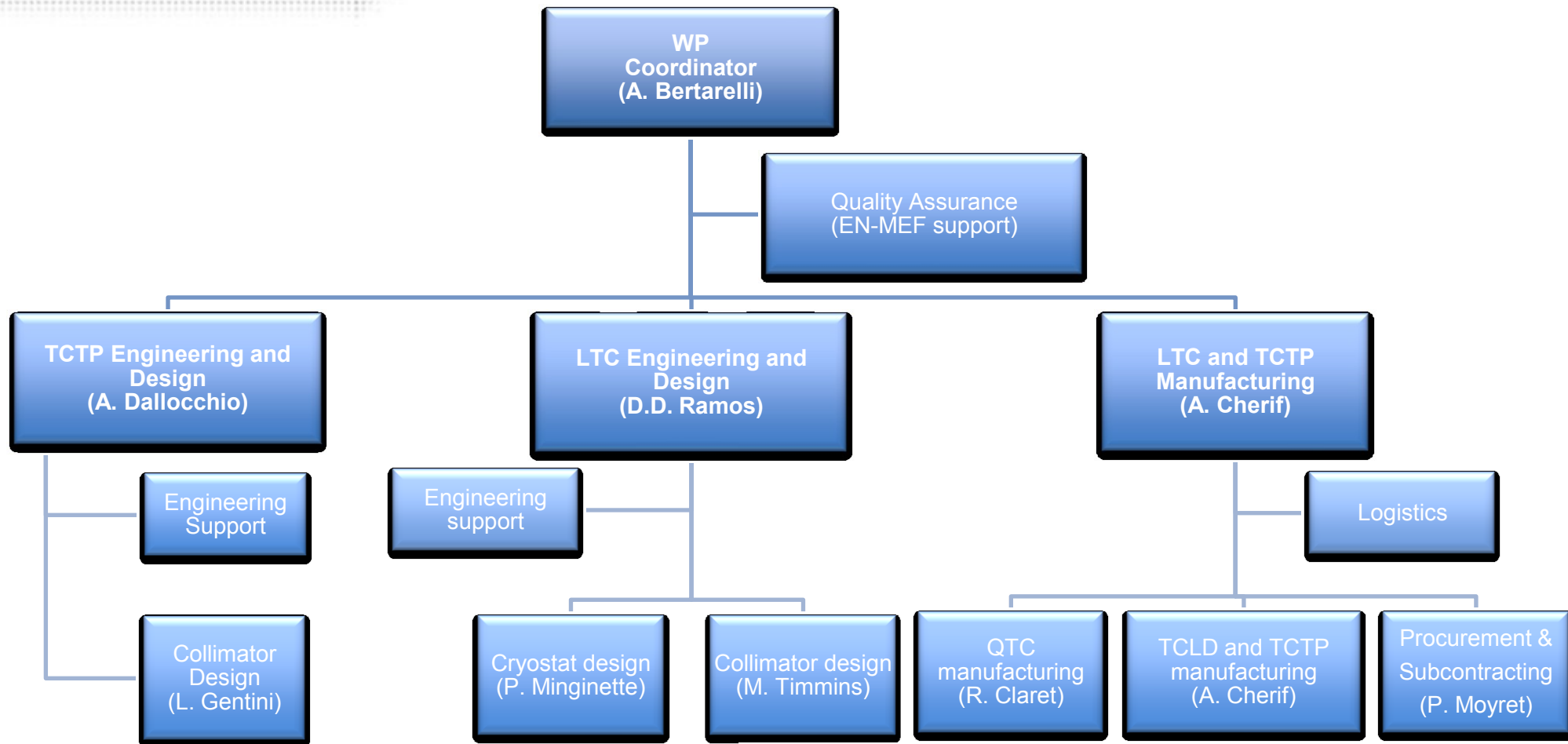
- Engineering & Design
- Manufacturing of 1 prototype.
- Procurement of raw material and strategic components.

4. **Phase 2 Advanced Collimators – 3 prototypes.**

- R&D, Engineering, Design
- Manufacturing of 3 prototypes.



WORK-PACKAGE ORGANISATION

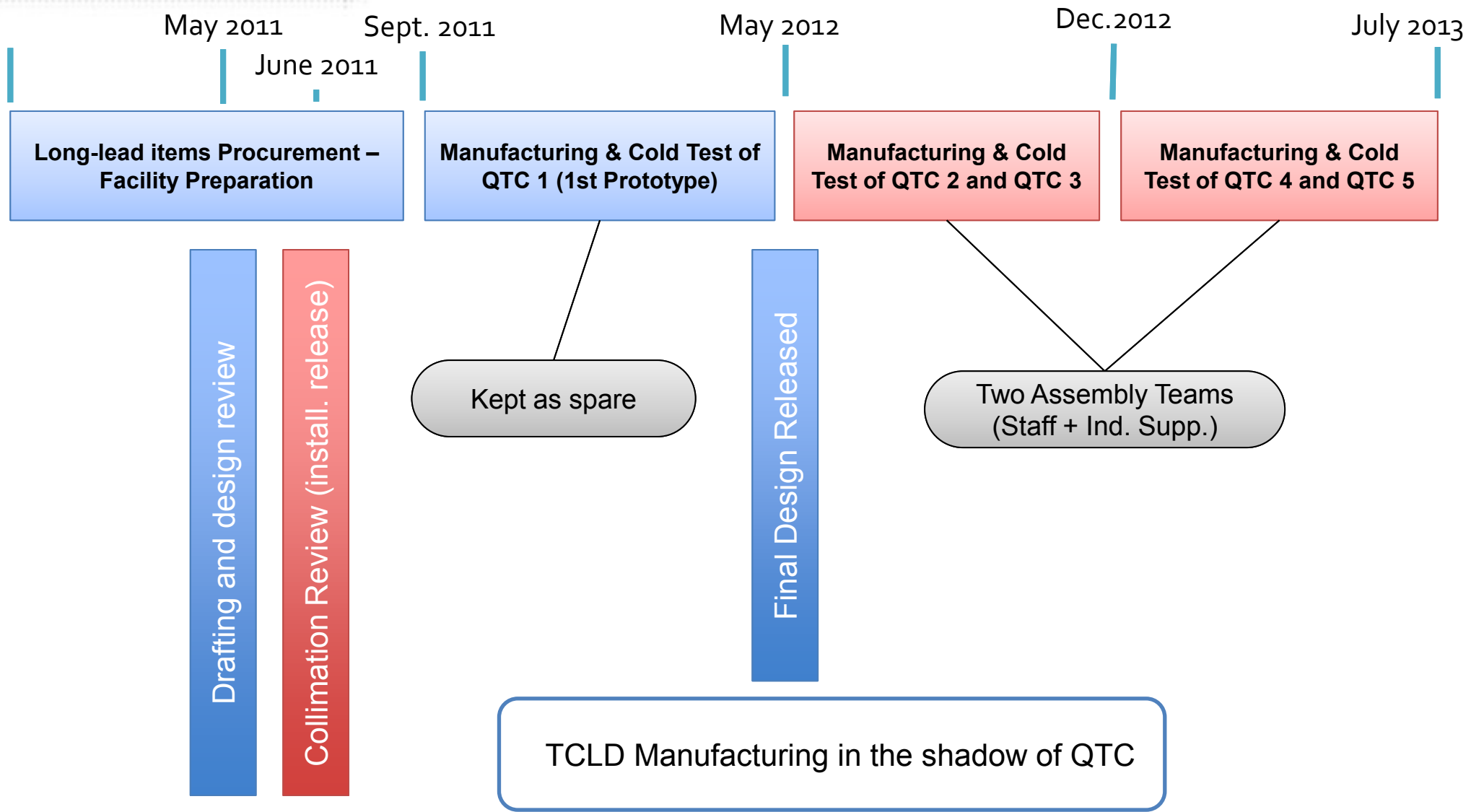


Phase 1+ and Phase 2 not shown

- **Extensively rely on existing/proven designs and technologies**
- **Co-Design / Close cooperation** with “Technology-owner” groups
 - Bus-bar (TE-MSD), UHV components (TE-VSC), Cryogenics (TE-CRG), Cold Tests (TE-MSD), Survey (BE-ABP), Fluka (EN-STI), Integration (EN-MEF), BPMs (BE-BI) ...
- **Extensive subcontracting of manufacturing**
 - Machined components, “controllable” welded components
- **In-house critical activities**
 - Critical welding, assembly, controls, tests ...
 - CERN resources complemented by Industrial Support contracts
- **Separate manufacturing lines** for TCLD and QTC
 - TCLD in specific facility at B.100
 - QTC in B.112 or SMI2 (feasibility analysis ongoing)



MANUFACTURING TIMELINE



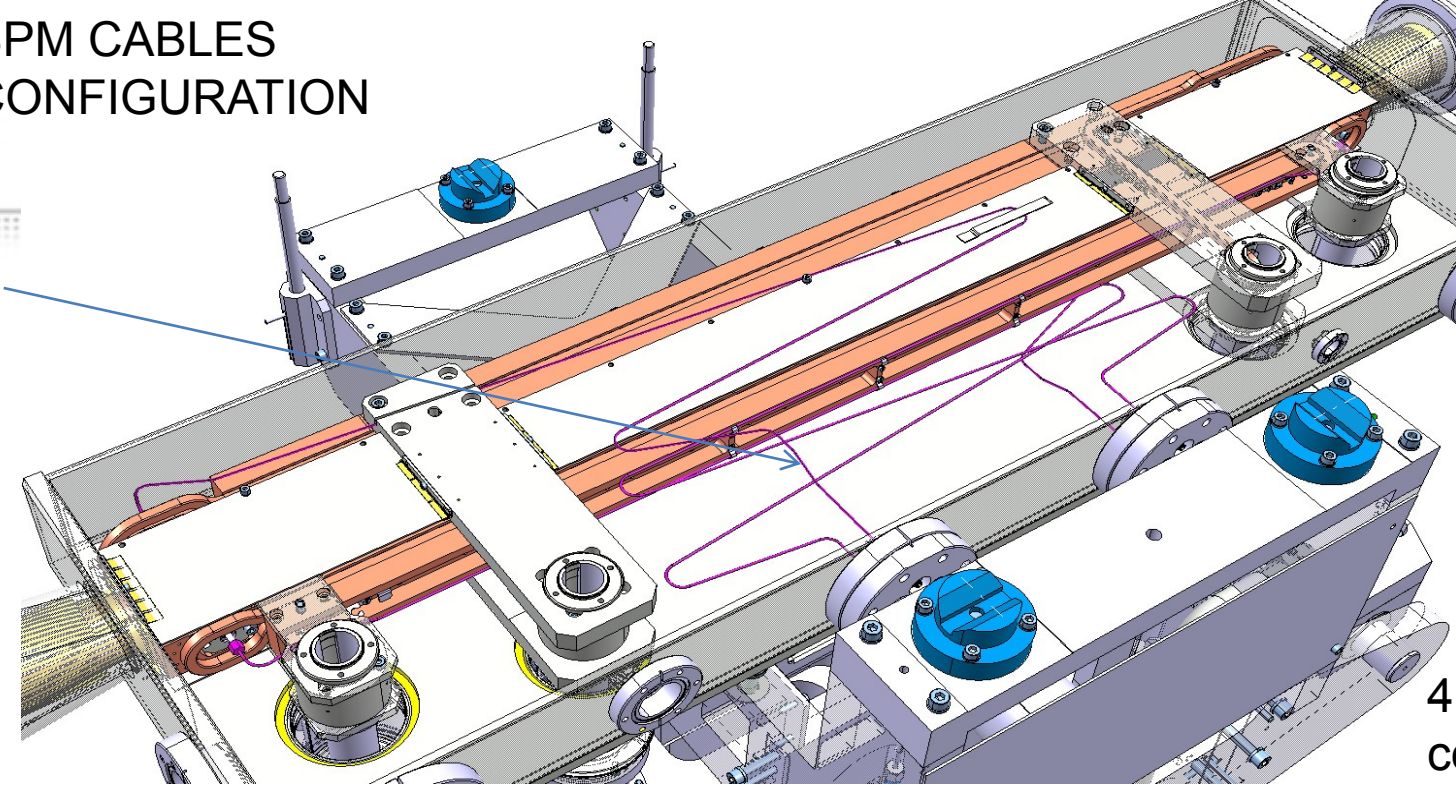
- Many interactions with several parties during assembly and testing phases.
- Use of subcontracted resources for QTC manufacturing requiring training and close follow-up.
- Risks of manufacturing conflict with other priority projects (Linac4, Shut-down preparation, other collimators) in case of delays.
- LTC production to end by late spring 2013. Conflicts in manpower allocation with Splice Consolidation cannot be ruled out.

Thank you for your attention!

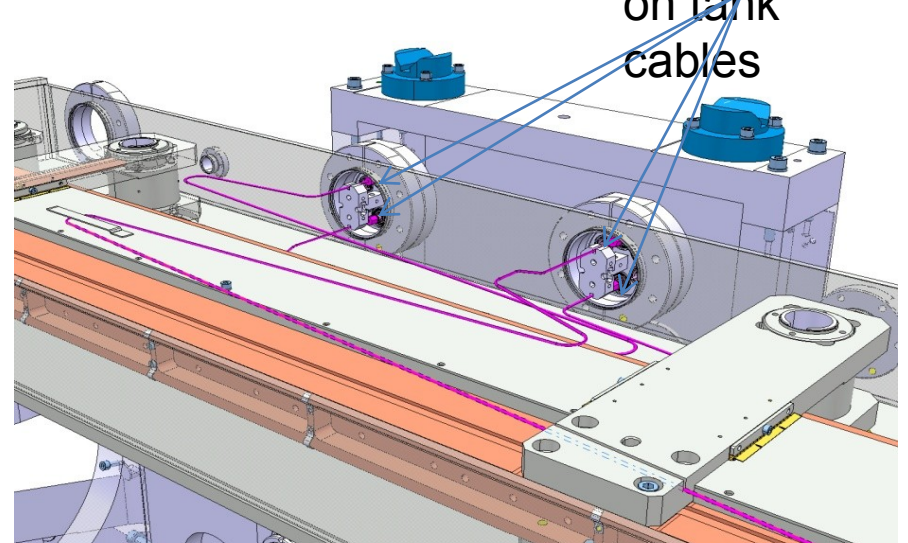
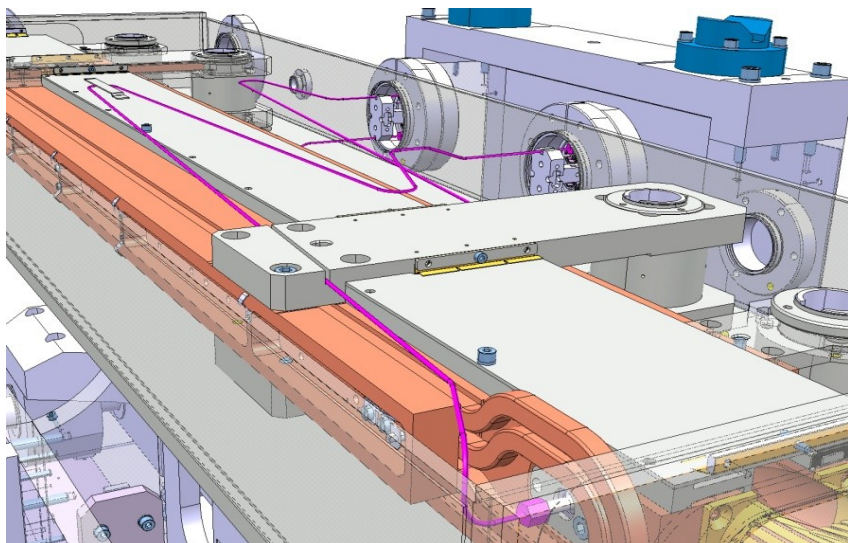


BPM CABLES CONFIGURATION

Cable routing



4 feedthrough connections on tank cables

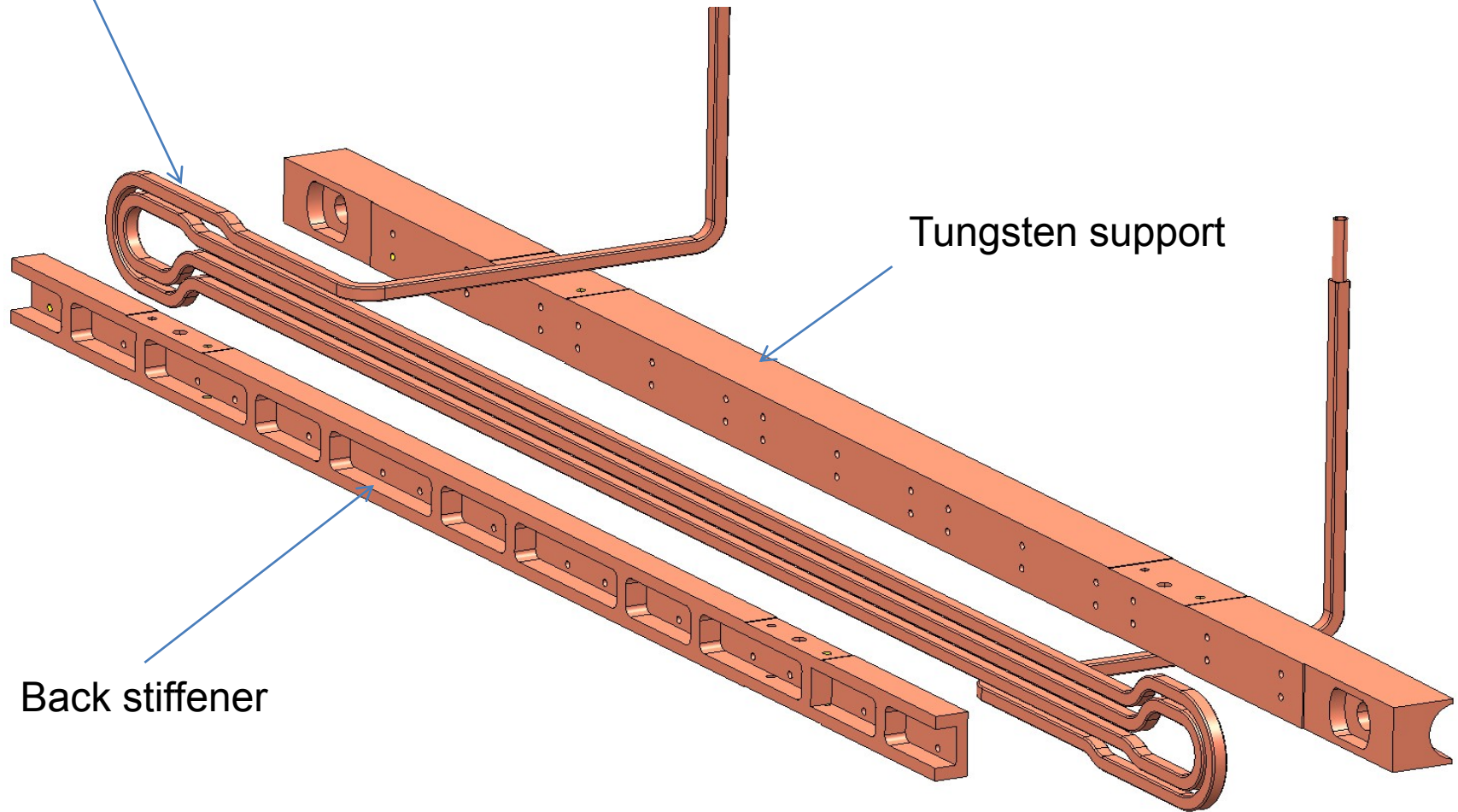


Cooling circuit

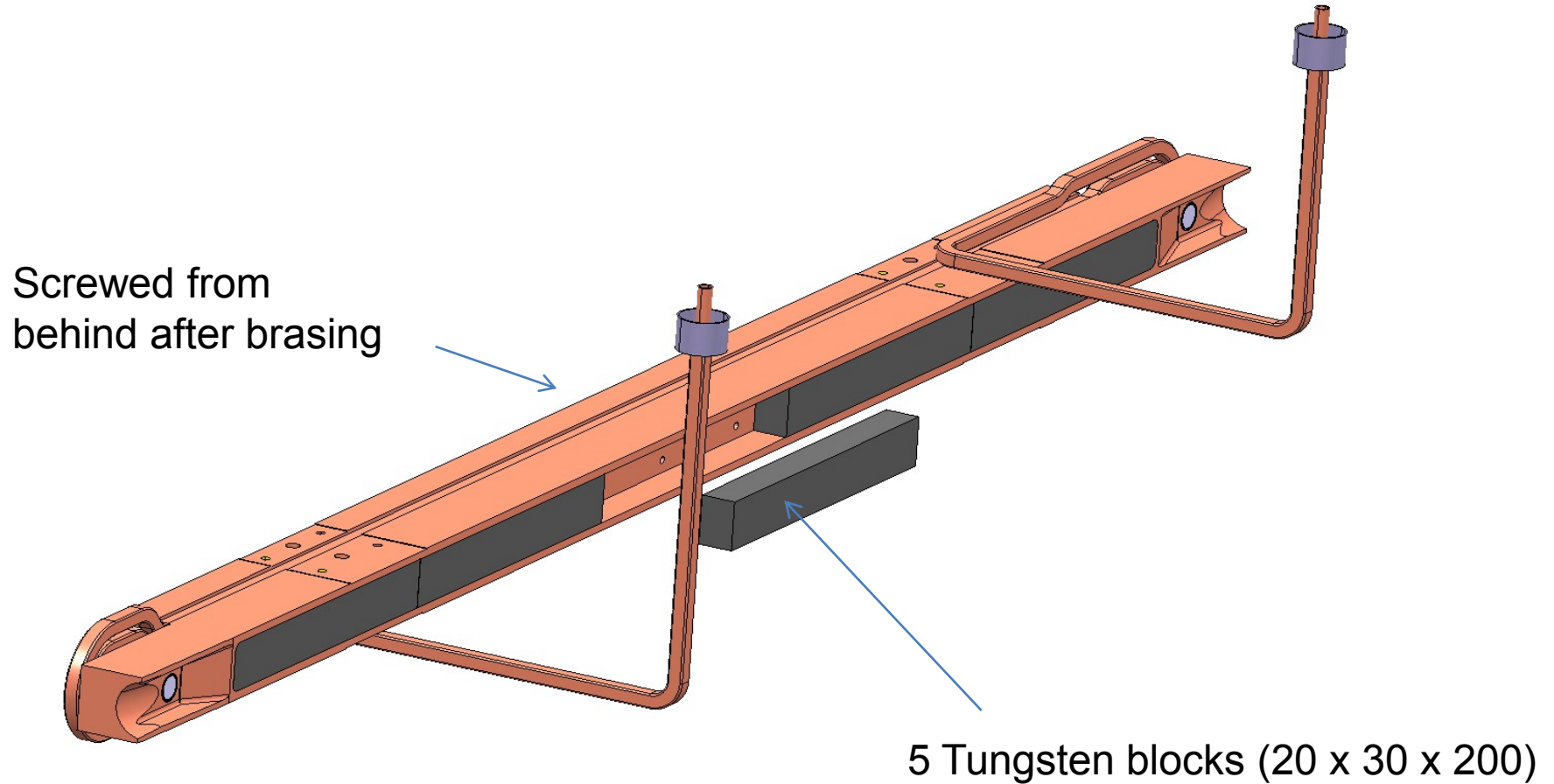
Brazed Jaw

Tungsten support

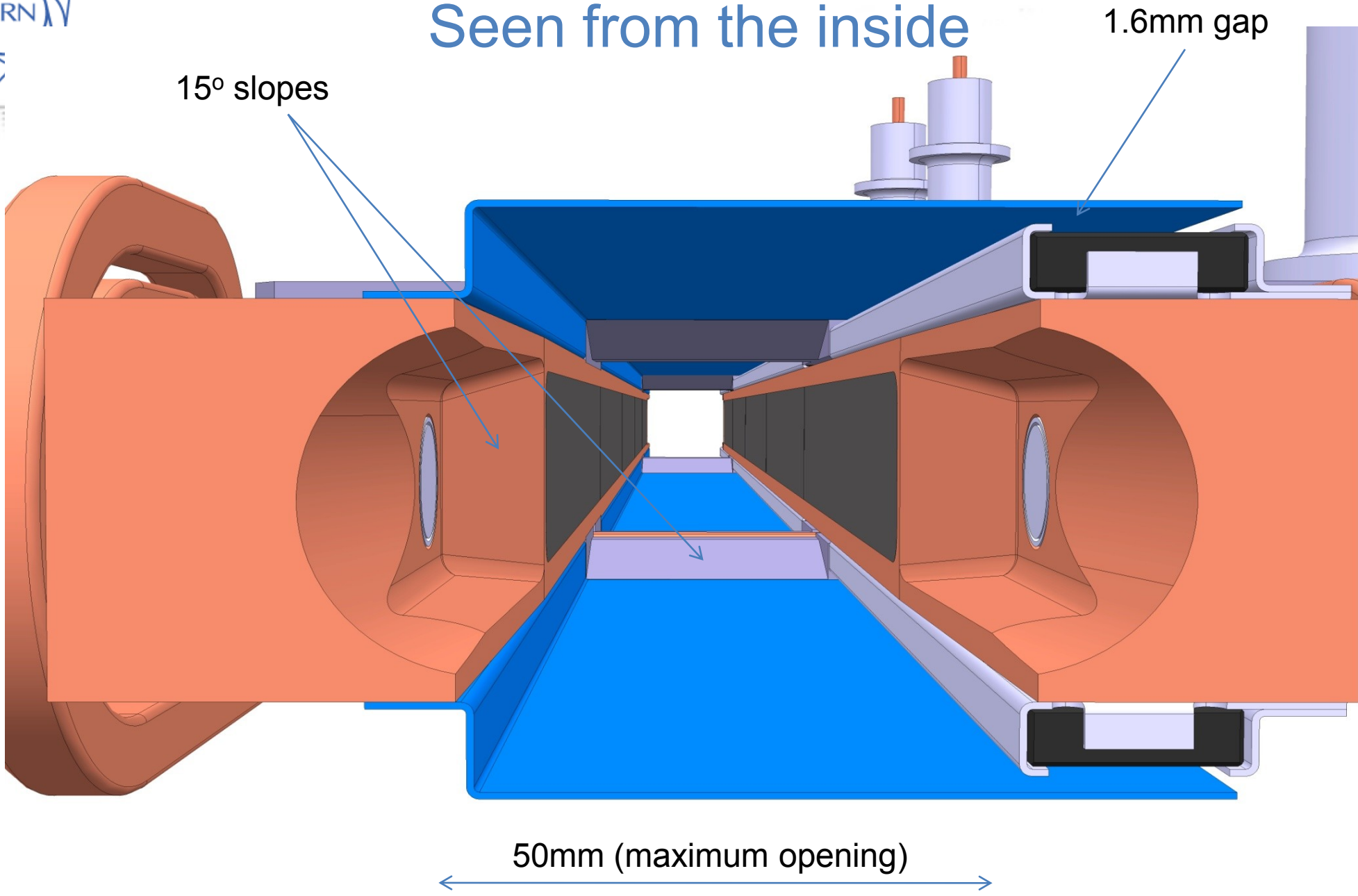
Back stiffener



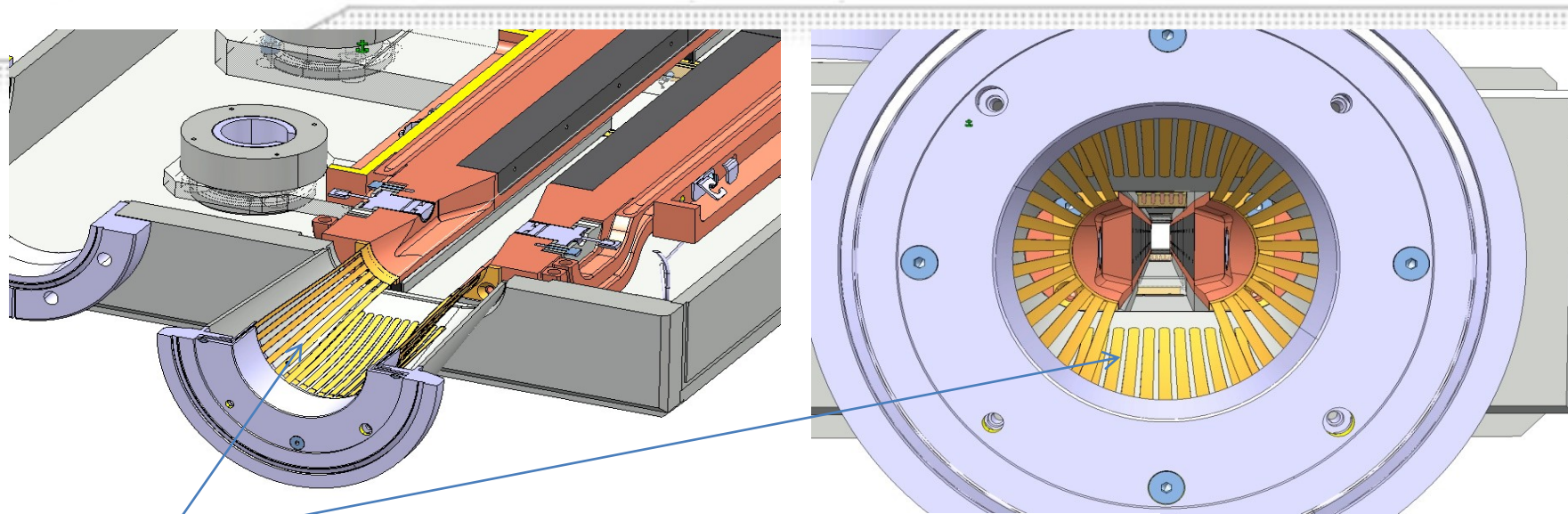
Tungsten block assembly



Seen from the inside



RF CONFIGURATION FOR TCLD COLLIMATOR – extra illustrations

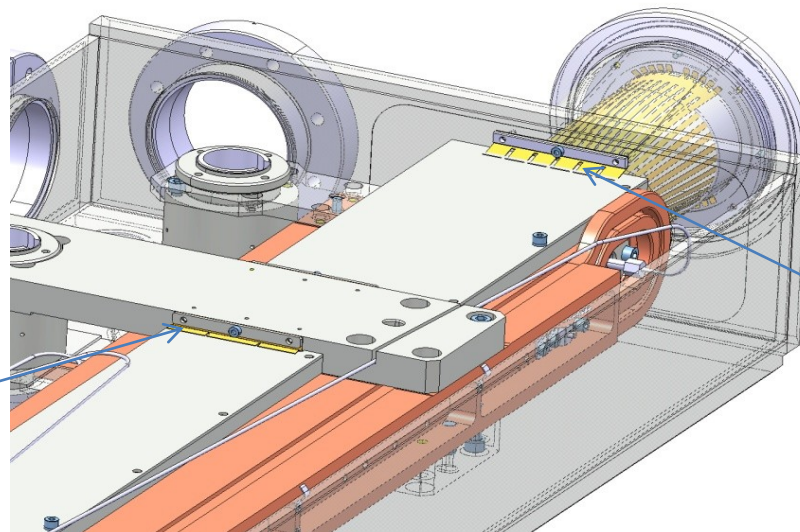


RF extremity fingers

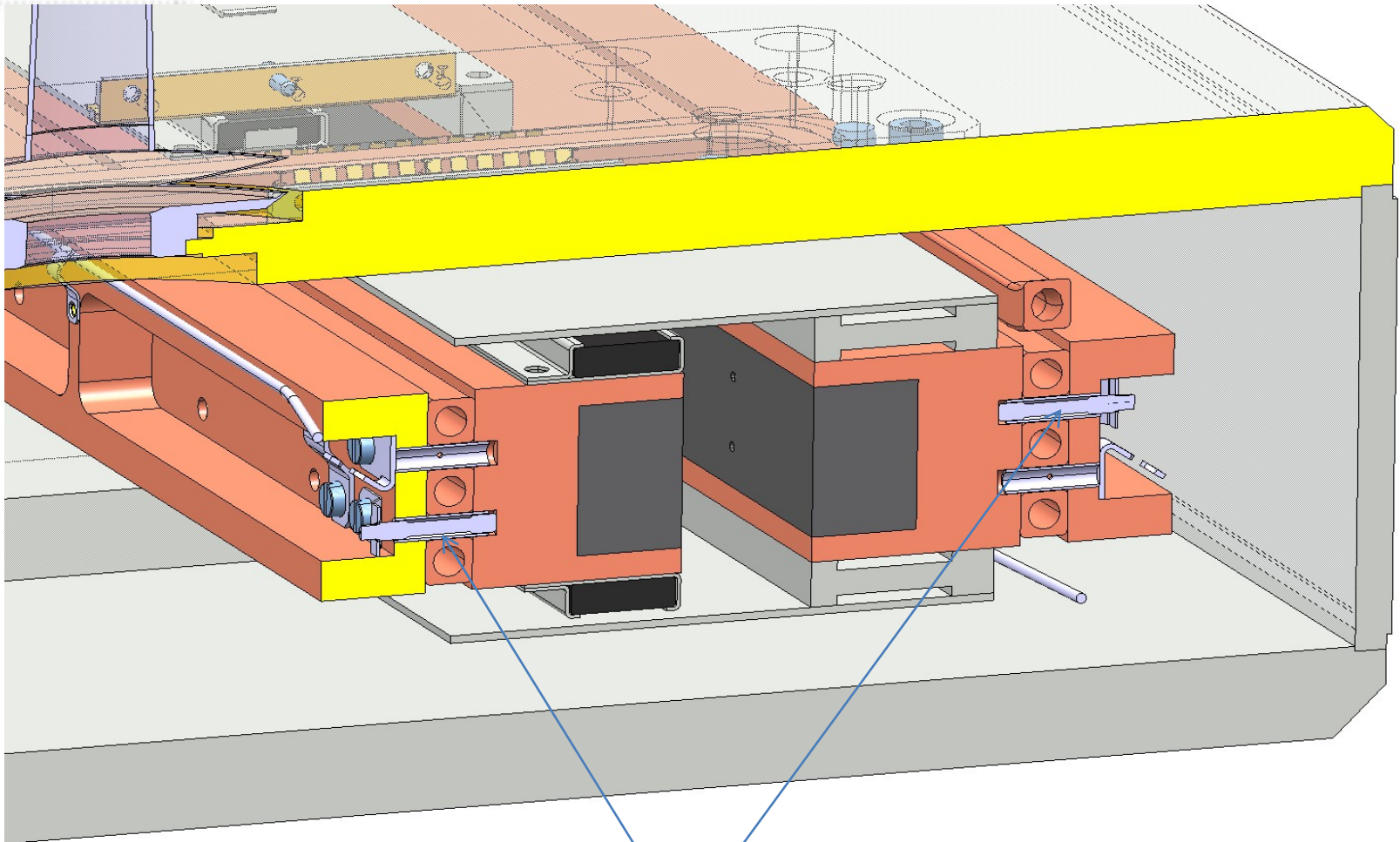
- Horizontal fixed contact
- Vertical mobile contact

RF screen contacts

RF screen/tank contact

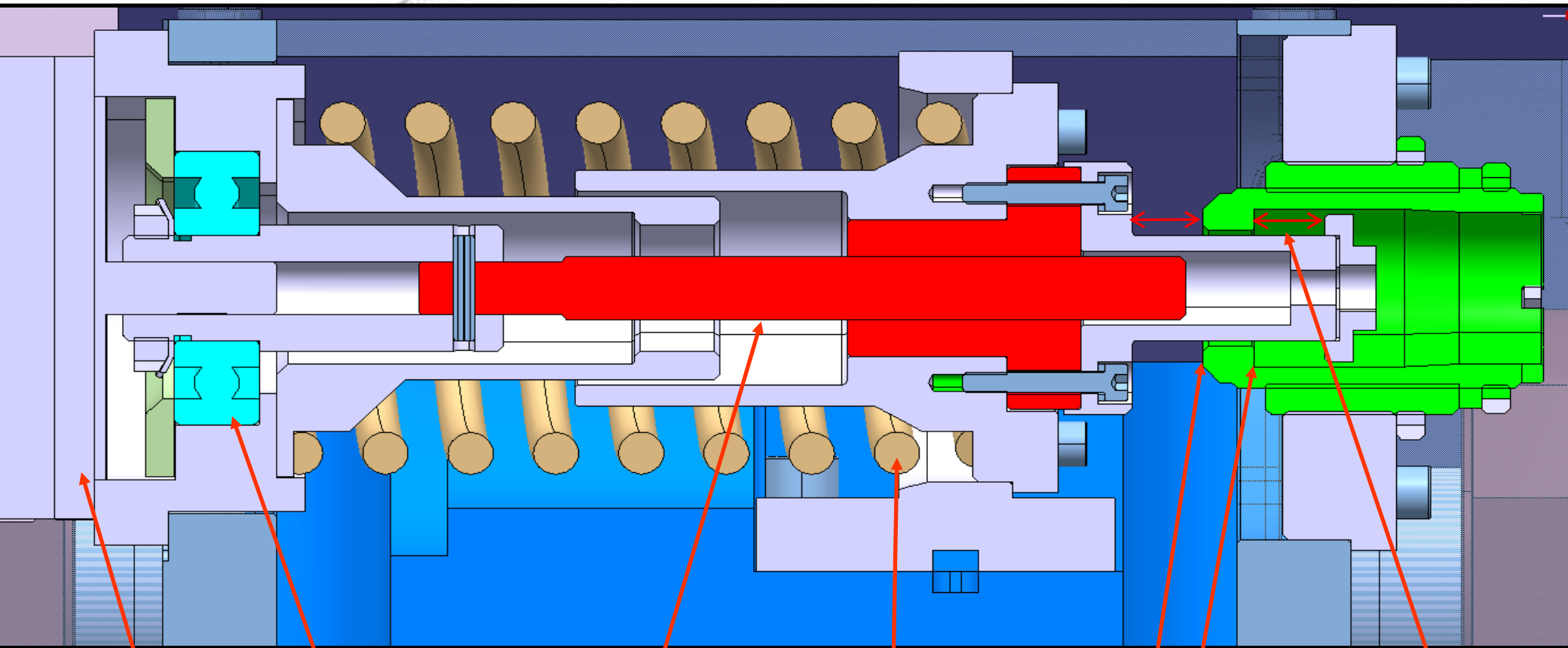


TEMP. PROBE CONFIGURATION



4 Temperature probes (1at
each jaw extremity)

ACTUATION SYSTEM



Step Motor

Bearing

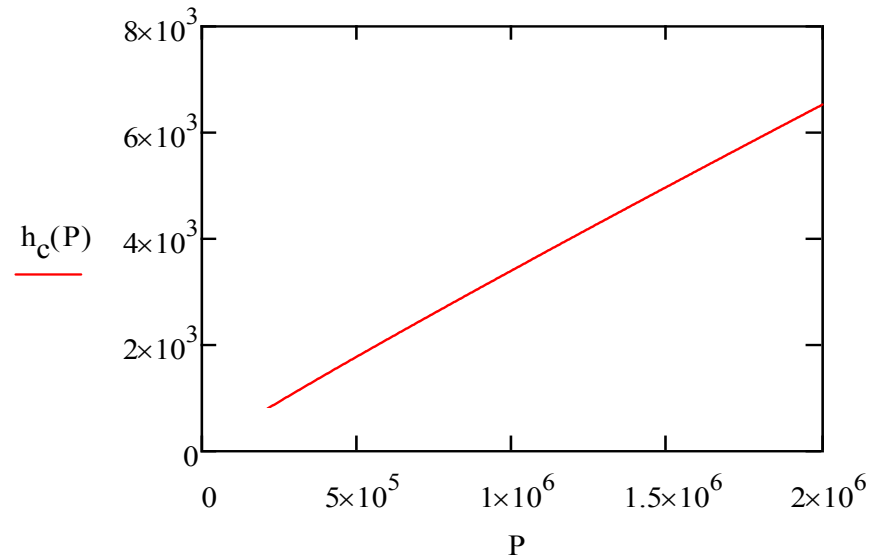
Roller screw

Spring

Mechanical Stops

Stroke adjustment

$$h_c(P) := 1.55 \cdot \frac{k_s \cdot \Delta_a}{R_q} \cdot \left(\frac{\sqrt{2} \cdot P}{E' \cdot \Delta_a} \right)^{0.94}$$



Glidcop to W

Pressure 15 bar

hc = ~5000 kW/m².K



Selection of ball bushings and lifetime estimation

Characteristics of the linear guide

Shaft diameter: $d = 40 \text{ mm}$
Sferax metric series "standard"
type 4060, page 25
Shaft type AX, page 54, inox DIN X90CrMoV18 1.4112, 59 HRC

Verification for static load

Static load capacity

$$P_s := 7350 \cdot N$$

Applied load

$$P := \max(W)$$

$$P = 588 \text{ N}$$

$$\frac{P_s}{P} = 13$$

static load is ok!

Dynamic verification

Dynamic factor Y

$$Y := 0.000130$$

Coefficient of shaf hardness, page 20, for 59 HRC

$$X := 1.12$$

Coefficient of the working life expectation

$$f_l := X \cdot Y \cdot P$$

$$f_l = 0.0856 \text{ N}$$

Life expectancy from diagram page 21 is $>100 \times 10^6 \text{ m}$

$$L_{\text{rated}} := 100 \cdot 10^6 \cdot \text{m}$$

Required life

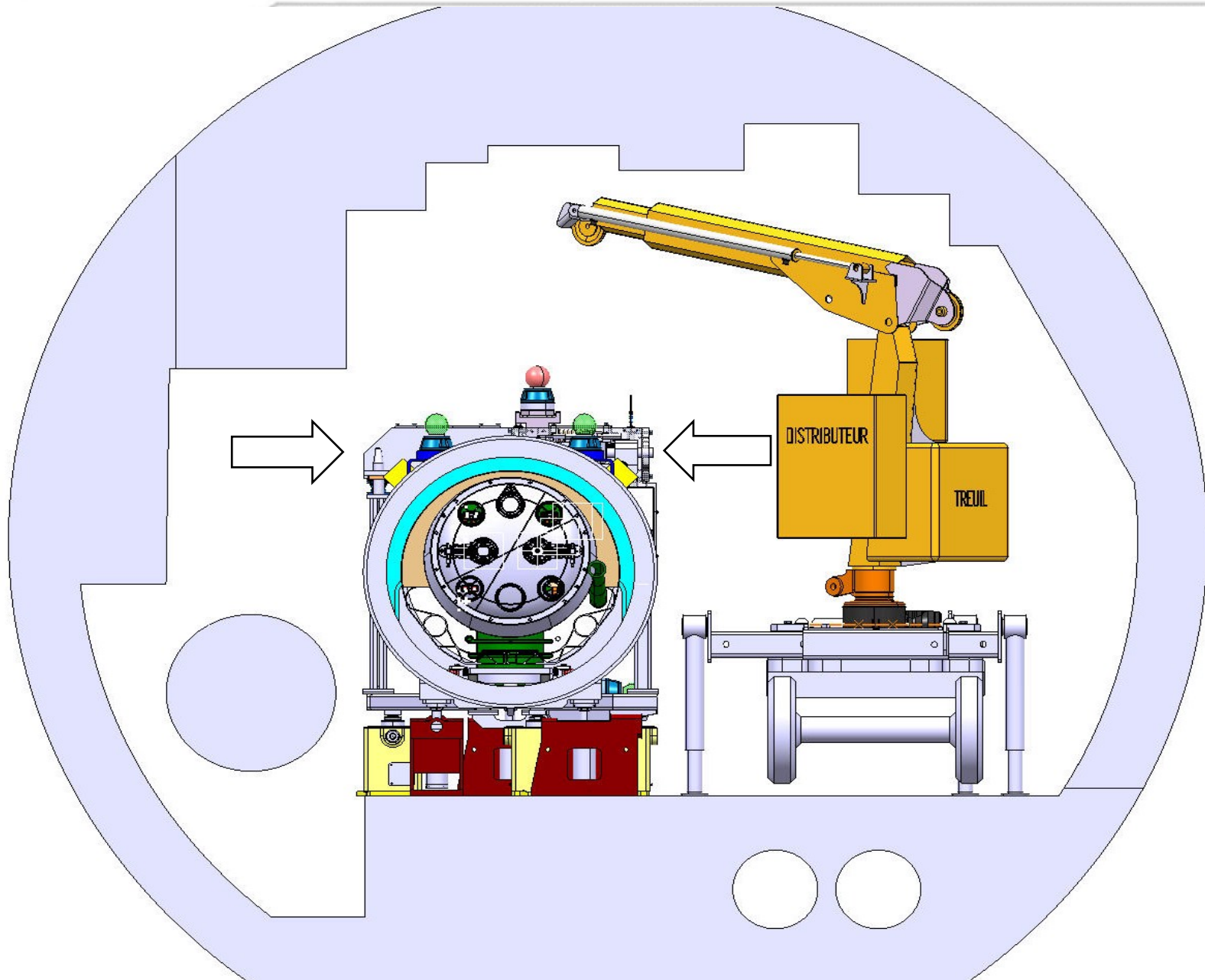
$$N := 20000$$

$$\text{stroke} := 30 \cdot \text{mm}$$

$$L_{\text{req}} := 2 \cdot \text{stroke} \cdot N$$

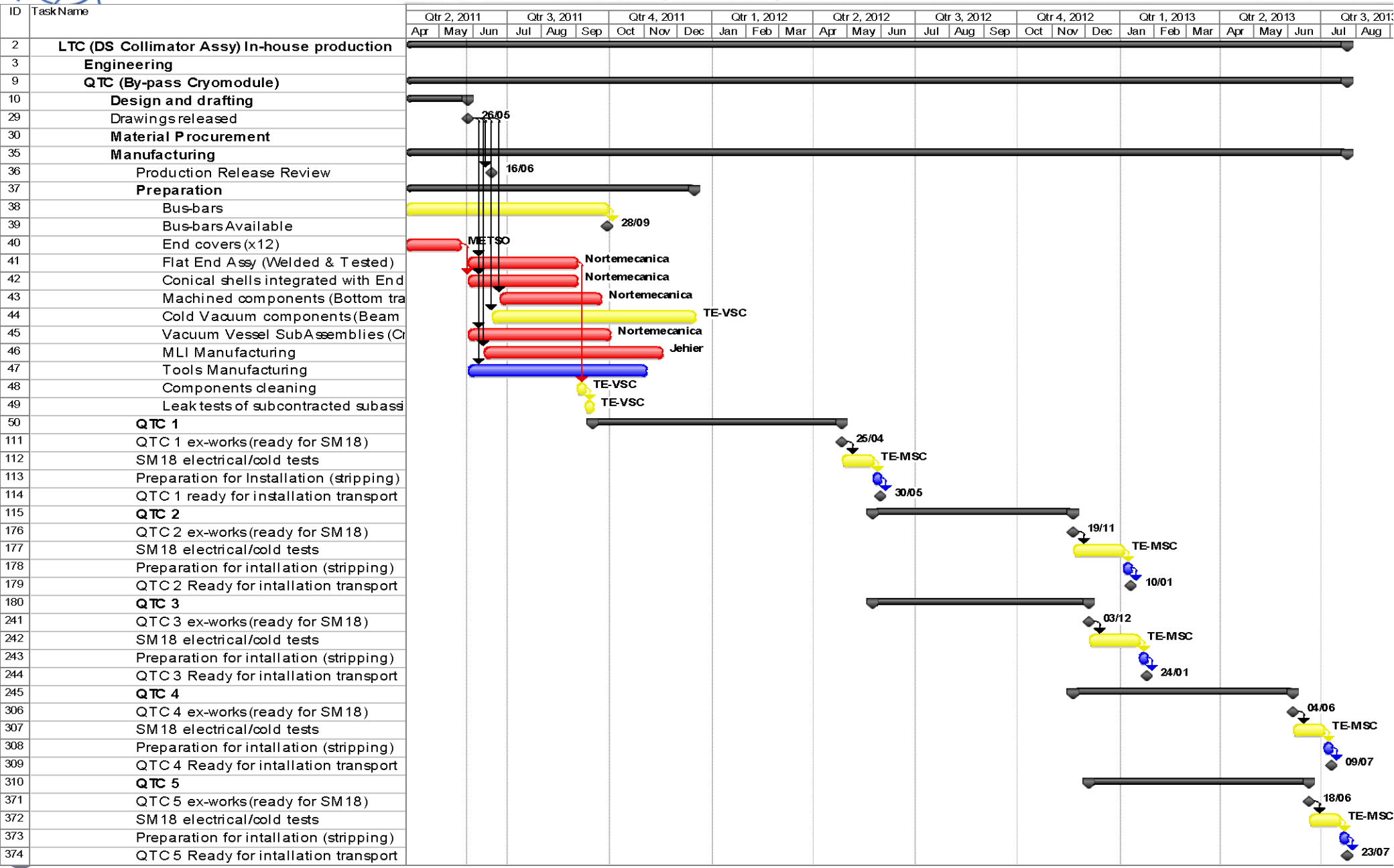
$$L_{\text{req}} = 1200 \text{ m}$$







SCHEDULE





DRAFT BUDGET

				Phase 1+					DS Collimators						
		Engineering		Updated design					Engineering, design						
Scope		Production		1 TCP + Plan B (backup production in case industry fails). Material procurement for Plan A and for equipment added after delivery (supports, plugins, cabling, support stands, cradles etc.) is not included in this budget even if done by MME.					5 LTC ex-works. The budget includes work provided by SU and VSC as embedded "service". Components provided by MSC, BI, VSC for the as-delivered product are not included. It does not include components added at a later stage, e.g. Vacuum valves and gauges, motorization, electronics etc.						
		Grand Total (To Be Provisioned)		Total (TBP)	Prov. (61711)	2011 (TBP)	2012	2013	2014	Total (TBP)	Prov. (61711)	2011 (TBP)	2012	2013	2014
Material (kCHF)	Total	8696.8		737.6	480.6	122.8	52.1	562.8	0.0	5949.0	1151.4	3095.6	2287.1	566.3	0.0
	Engineering	Sub-Total	971.6	30.6	0.0	12.8	5.1	12.8	0.0	306.0	285.6	204.0	91.8	10.2	0.0
	Production	Sub-Total	7725.2	707.0	480.6	110.0	47.0	550.0	0.0	5643.0	865.8	2891.6	2195.3	556.1	0.0
Personnel (FTE)	Total	43.8		1.4	0.2	0.8	0.4	0.0	0.0	20.4	5.7	7.8	6.9	3.5	0.0
	Engineering	Sub-Total	18.6	0.5	0.0	0.4	0.1	0.0	0.0	7.0	3.5	3.5	2.3	1.2	0.0
		Staff	15.0	0.4	0.0	0.3	0.1	0.0	0.0	6.2	3.5	3.2	2.0	1.0	0.0
		Fellows	3.6	0.1	0.0	0.1	0.0	0.0	0.0	0.8	0.0	0.3	0.3	0.2	0.0
	Production	Sub-Total	25.2	0.9	0.2	0.4	0.3	0.0	0.0	13.4	2.2	4.3	4.6	2.3	0.0
		Staff	18.5	0.7	0.2	0.4	0.3	0.0	0.0	8.9	2.0	3.5	3.6	1.8	0.0
Fellows		2.3	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.2	0.8	1.0	0.5	0.0	



DRAFT BUDGET

		Tertiary Collimators with BPM							Phase 2							
Scope		Engineering		Engineering, design							R&D, Engineering, design					
		Production		1 TCTx							3 prototypes					
		Grand Total (To Be Provisioned)		Total (TBP)	Prov. (61711)	2011 (TBP)	2012	2013	2014	Total (TBP)	Prov. (61711)	2011 (TBP)	2012	2013	2014	
Material (kCHF)	Total	8696.8		482.9	0.0	245.7	212.0	25.2	0.0	1527.3	552.1	237.0	458.9	548.1	283.3	
	Engineering	Sub-Total	971.6	79.1	0.0	53.6	25.5	0.0	0.0	555.9	127.5	51.0	165.2	229.5	110.2	
	Production	Sub-Total	7725.2	403.8	0.0	192.2	186.5	25.2	0.0	971.4	424.6	186.0	293.6	318.6	173.1	
Personnel (FTE)	Total	43.8		3.8	0.0	1.9	1.9	0.0	0.0	18.2	4.5	2.4	4.1	5.2	4.5	
	Engineering	Sub-Total	18.6	2.4	0.0	1.5	0.9	0.0	0.0	8.7	2.5	1.2	2.3	2.7	2.5	
		Staff	15.0	1.6	0.0	1.0	0.6	0.0	0.0	6.8	1.5	0.8	1.8	2.2	2.0	
		Fellows	3.6	0.8	0.0	0.5	0.3	0.0	0.0	1.9	1.0	0.4	0.5	0.5	0.5	
	Production	Sub-Total	25.2	1.4	0.0	0.4	1.0	0.0	0.0	9.5	2.0	1.2	1.8	2.5	2.0	
		Staff	18.5	1.4	0.0	0.4	1.0	0.0	0.0	7.5	2.0	1.2	1.8	2.5	2.0	
Fellows		2.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		



Collimation Upgrade Spending for Manufacturing (2010 - Jan 2011)

