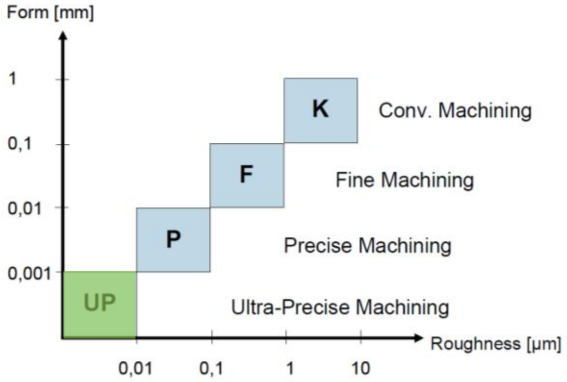
Review of X-band session

Walter Wuensch, CERN

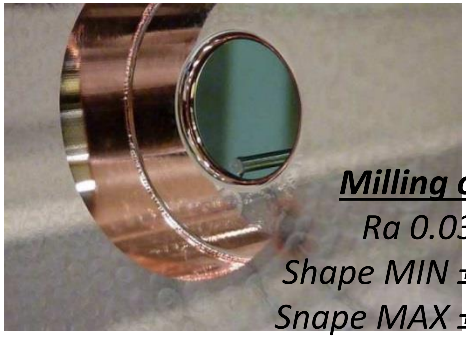
Machining. Technology

CLIC's needs:
shape accuracy± 2.5 μm
Roughness Ra 25 nm



S. Atieh

Study:
- Use only milling technology



Milling of iris:
Ra 0.032 μm
Shape MIN ±2 μm
Snape MAX ±5 μm

Damped disc

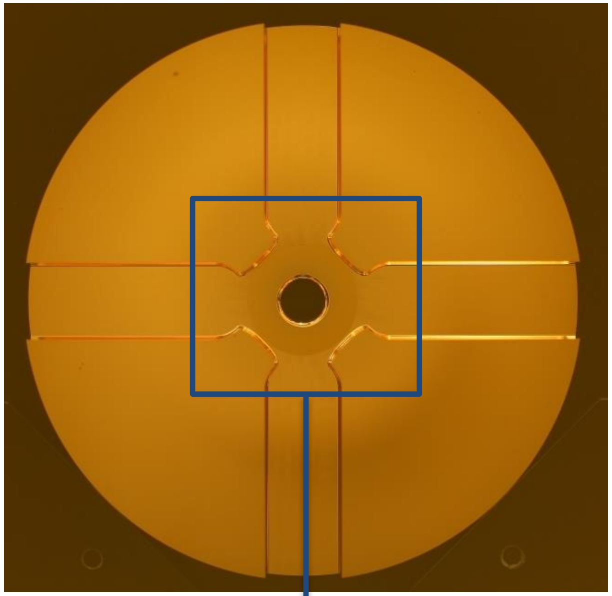
Machining strategy differs from company to company

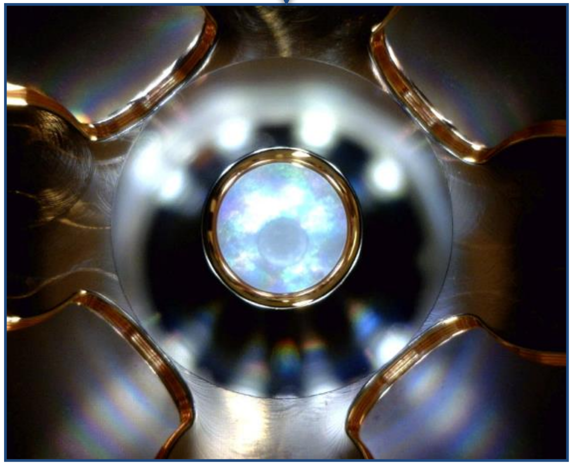
Pre machining

- **Sawing**
- **Pre-Turning**
- **Pre-milling**
- **Drilling tuning holes**
- (Measurement)
- (Annealing)

End machining

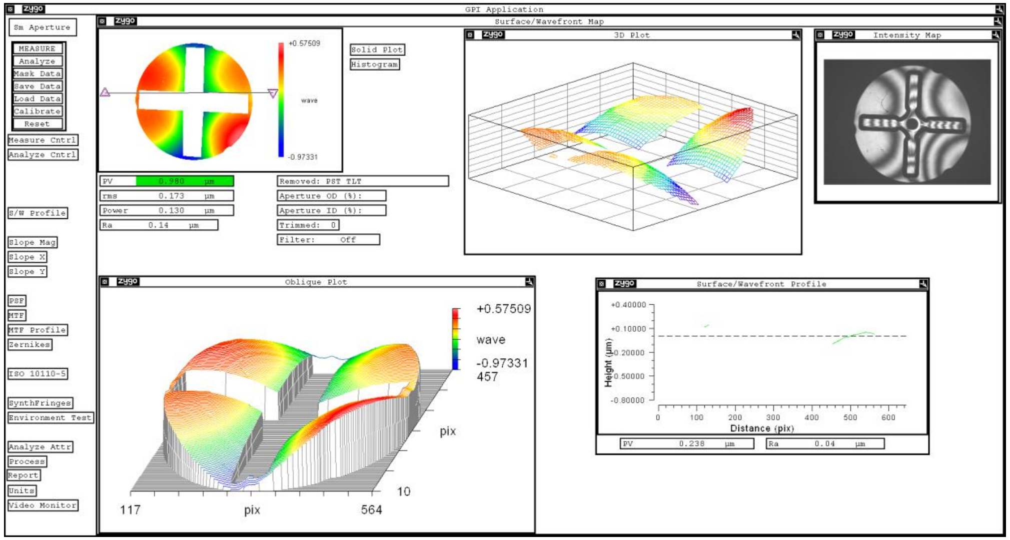
- **UP turning side waveguides**
- **UP turning opposite side**
- **UP milling waveguides**
- **Iris final turning**
- (Metrology)
- (Cleaning)





Machining. Dimensional control

Flatness / roughness control



All dimensional checks

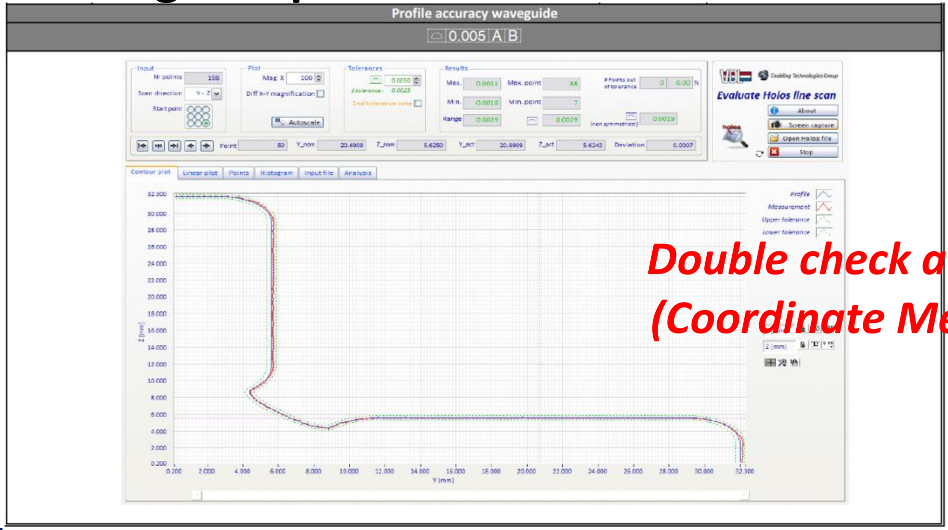
Enabling Technologies Group — **Inspection Report**

Drawing no.	CLIAAS120064	**Prod. Nr.**	2
Description	Disk 01		

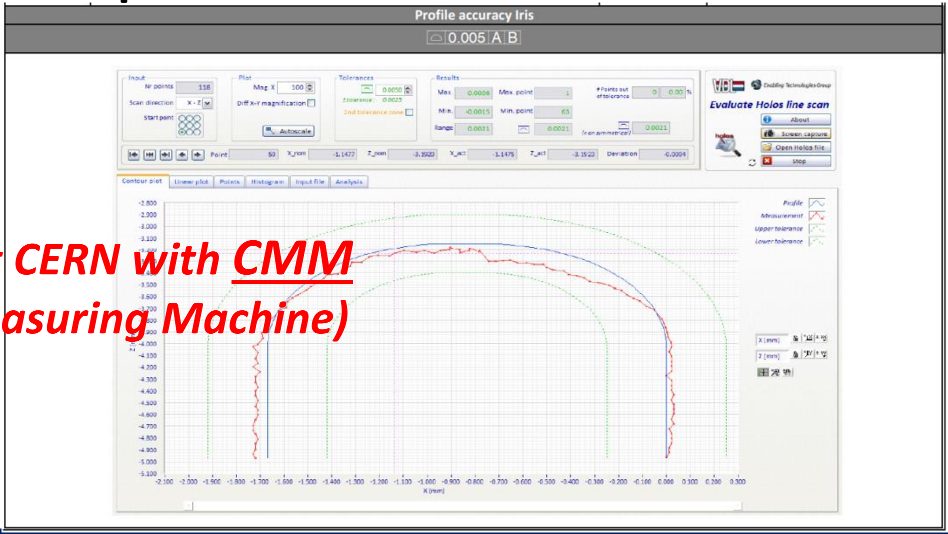
Dimensions

Measurand	Description	Nominal	Upper	Lower	Actual	Deviation	Pass √	Fail √	Remark
1	Ref A ▱ 0.002	0.0000	0.0020	0.0000	0.0013	0.0013	√		
2	Outer diameter Ref B	74.0000	0.0025	-0.0025	74.0002	0.0002	√		
3	▱ 0.002 ref B	0.0000	0.0020	0.0000	0.0009	0.0009	√		
4	⊥ 0.002 A	0.0000	0.0020	0.0000	0.0002	0.0002	√		
5	Diameter 70	70.0000	0.0000	-0.0100	69.9953	-0.0047	√		
6	◎ 0.005 B	0.0000	0.0050	0.0000	0.0003	0.0003	√		
7	Diameter 2xa	6.3000	0.0050	-0.0050	6.2996	-0.0004	√		
8	Distance d	8.3098	0.0020	-0.0020	8.3105	0.0007	√		
9	Plane at distance d ▱ 0.002	0.0000	0.0020	0.0000	0.0014	0.0014	√		
10	Diameter 70	70.0000	0.0150	0.0100	70.0129	0.0129	√		
11	◎ 0.005 B	0.0000	0.0050	0.0000	0.0011	0.0011	√		
12	Distance t	1.6700	0.0025	-0.0025	1.6705	0.0005	√		
13	Distance g	6.6398	0.0025	-0.0025	6.6396	-0.0002	√		
14	Width cross Z+	11.2500	0.0025	-0.0025	11.2503	0.0003	√		
15	Symmetry cross Z +	0.0000	0.0025	-0.0025	-0.0003	-0.0003	√		
16	Width cross Z-	11.2500	0.0025	-0.0025	11.2510	0.0010	√		
17	Symmetry cross Z -	0.0000	0.0025	-0.0025	-0.0004	-0.0004	√		
18	Width cross Y-	11.2500	0.0025	-0.0025	11.2499	-0.0001	√		
19	Symmetry cross Y -	0.0000	0.0025	-0.0025	0.0007	0.0007	√		

Waveguide profile check



Iris profile check



Double check at CERN with <u>CMM</u>
(Coordinate Measuring Machine)

Diffusion bonding. Process

Assembly process

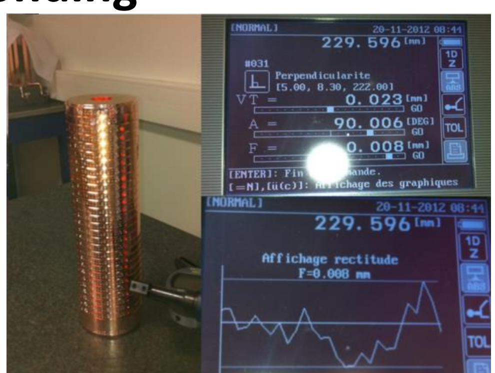
Process

- Assembly in V-shape column
- Straightness and tilt measurements before bonding
- Weight application
- Bonding
- Straightness and tilt measurement after bonding

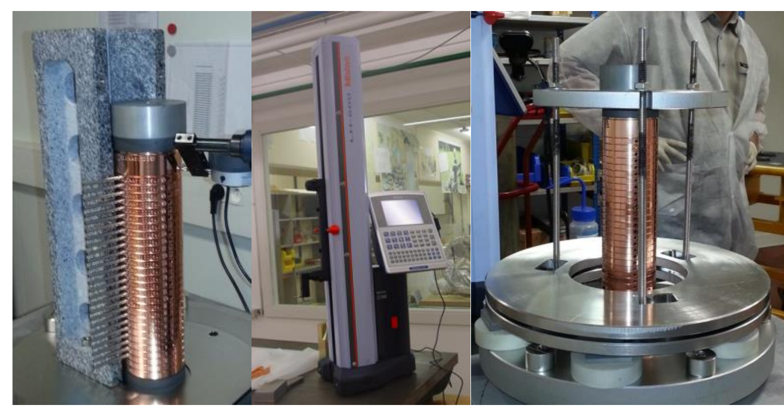
Equipment

- V-shape column
- Measurement column
- Tooling for the weight application
- Graphite/ceramic pads

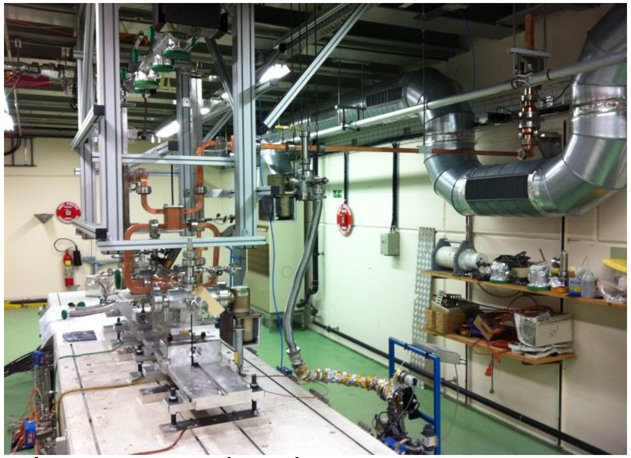
Straightness measurements before and after bonding

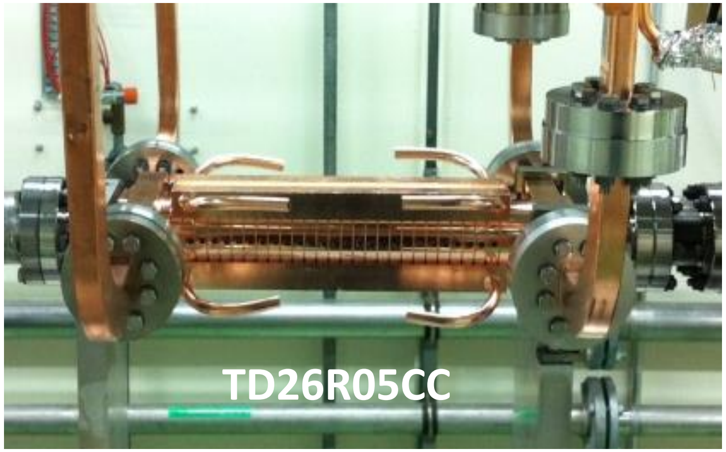


Equipment

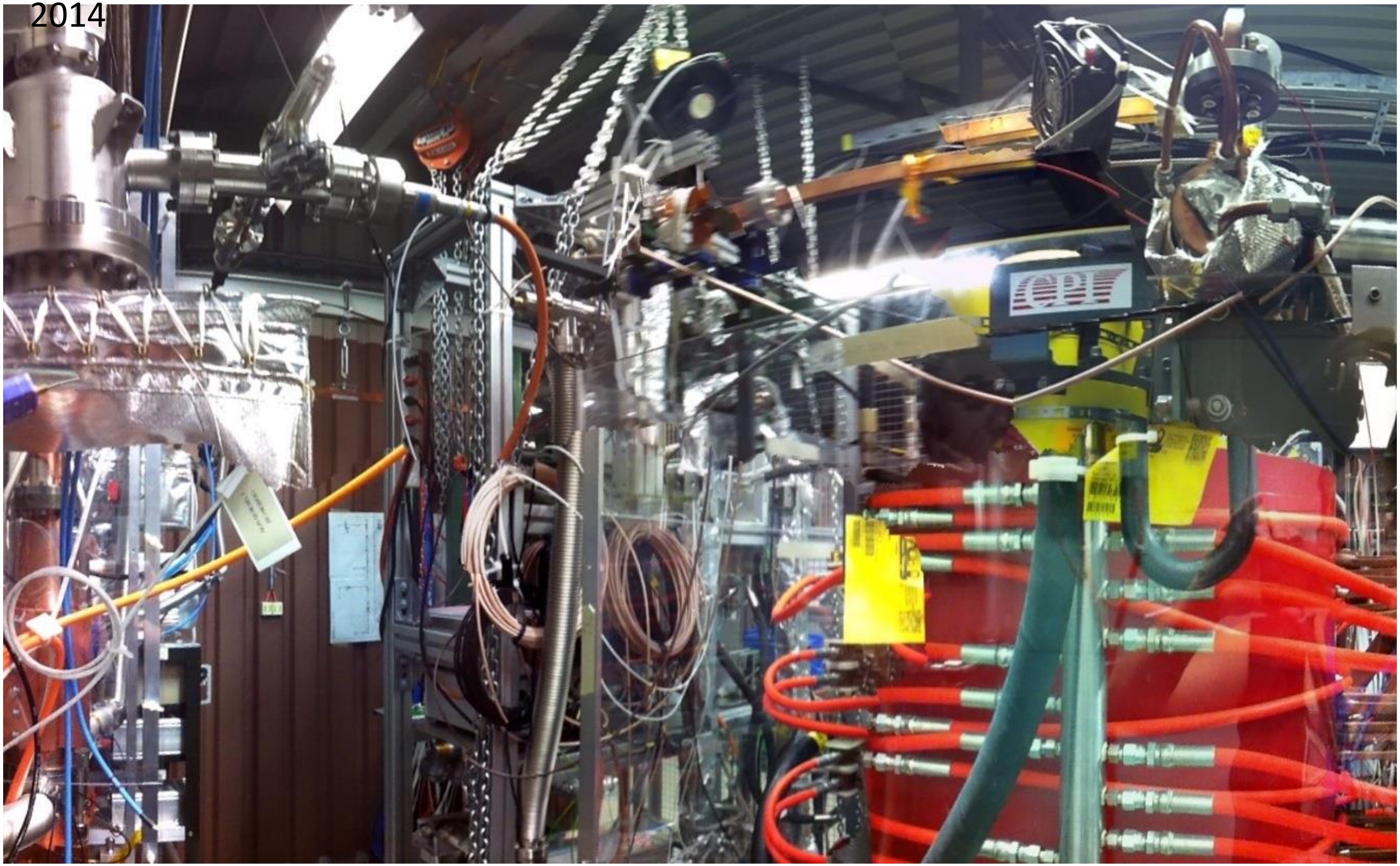


XBOX1 is up and running for almost 3 years

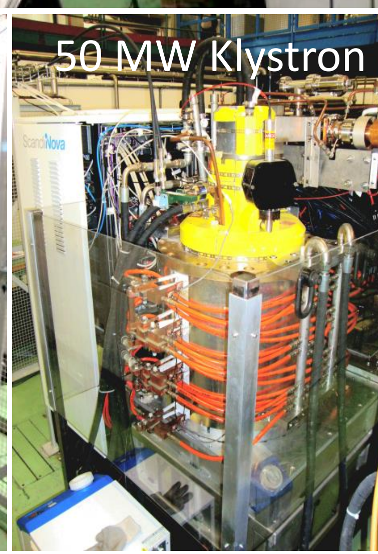


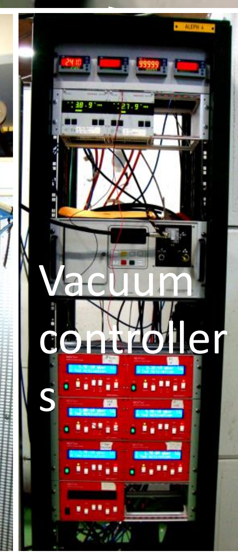


The first commercial (CPI) 50 MW 12 GHz klystron is in operation in XBOX#1 since June 2014

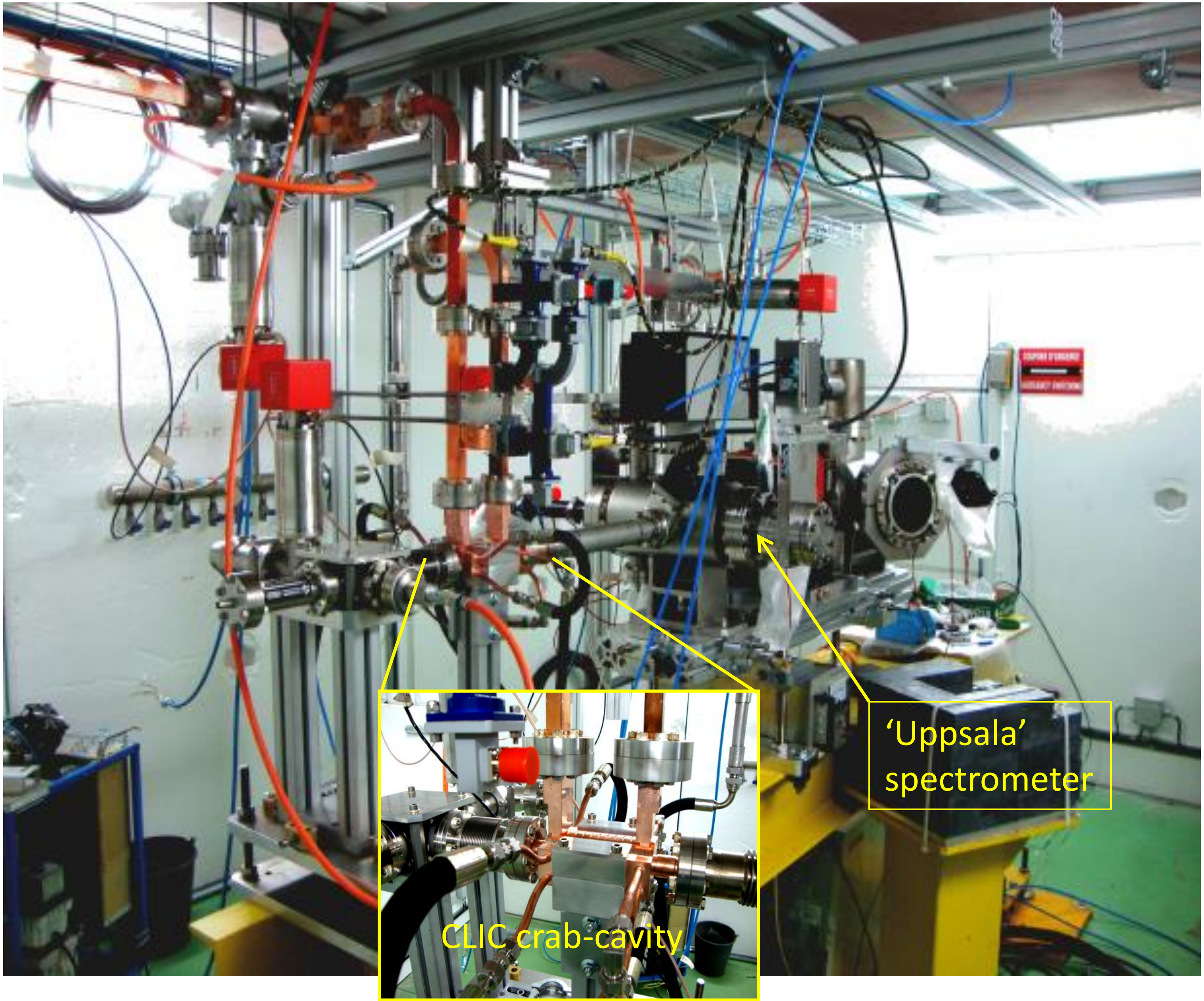


High RF power X-band test station XBOX#2

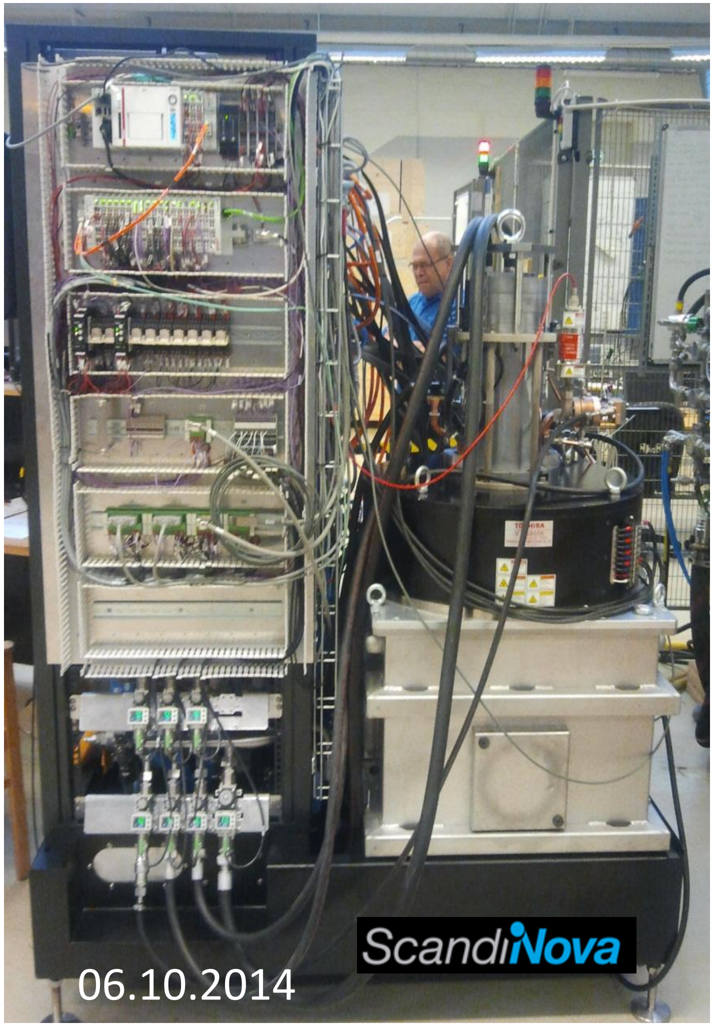




Inside of XBOX#2 test area



Factory tests at ScandiNova

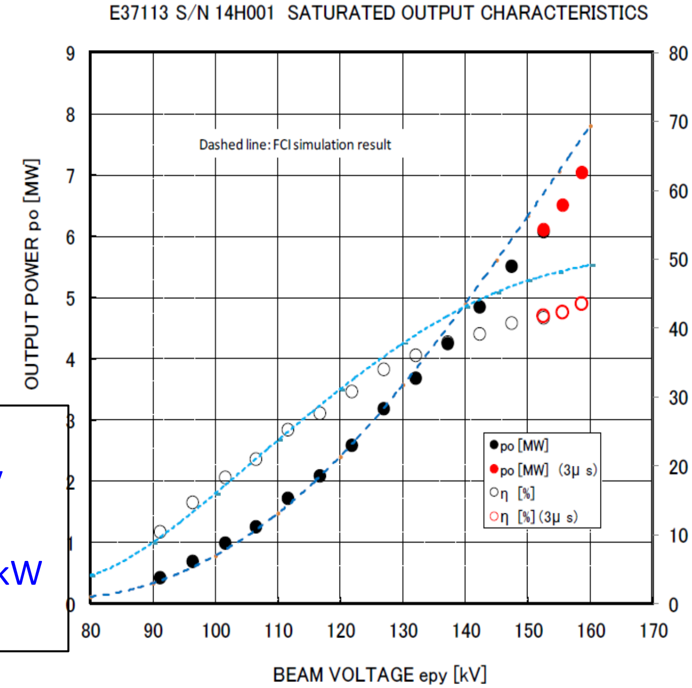


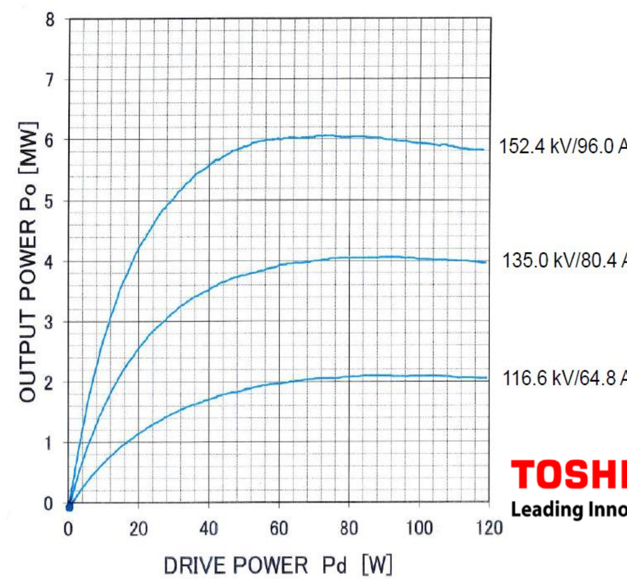
Design:

Peak power: 6 MW
Beam Voltage: 150 kV
Beam current: 90 A
Average power: 12.4 kW
Efficiency: 47.5%

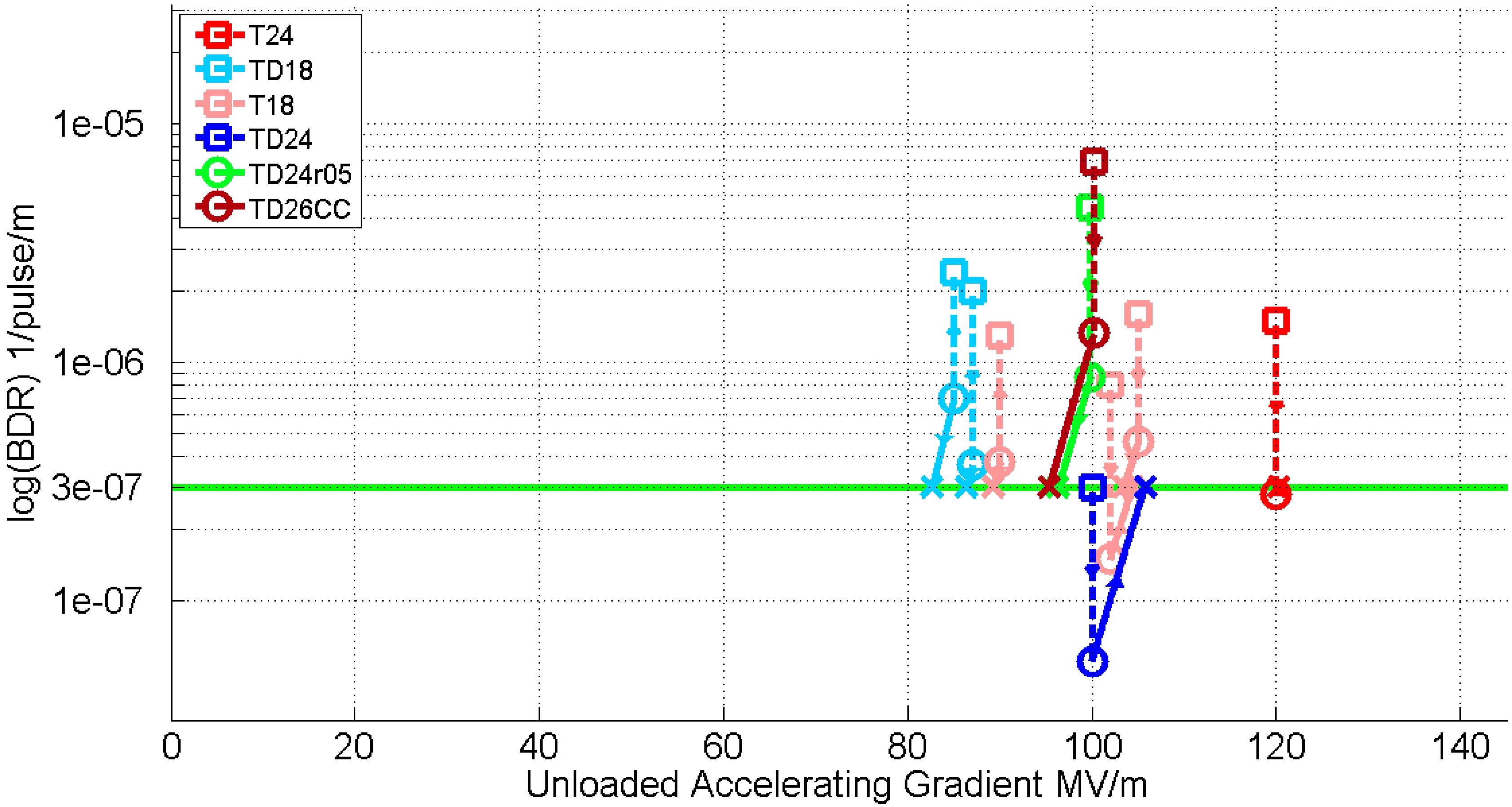
- 4 turn-key 6 MW, 11.9942 GHz power stations (klystron/modulator) have been ordered from industry.
- The first unit is scheduled to arrive at CERN in October 2014. The full delivery will be completed before July 2015.

Factory tests results at Toshiba

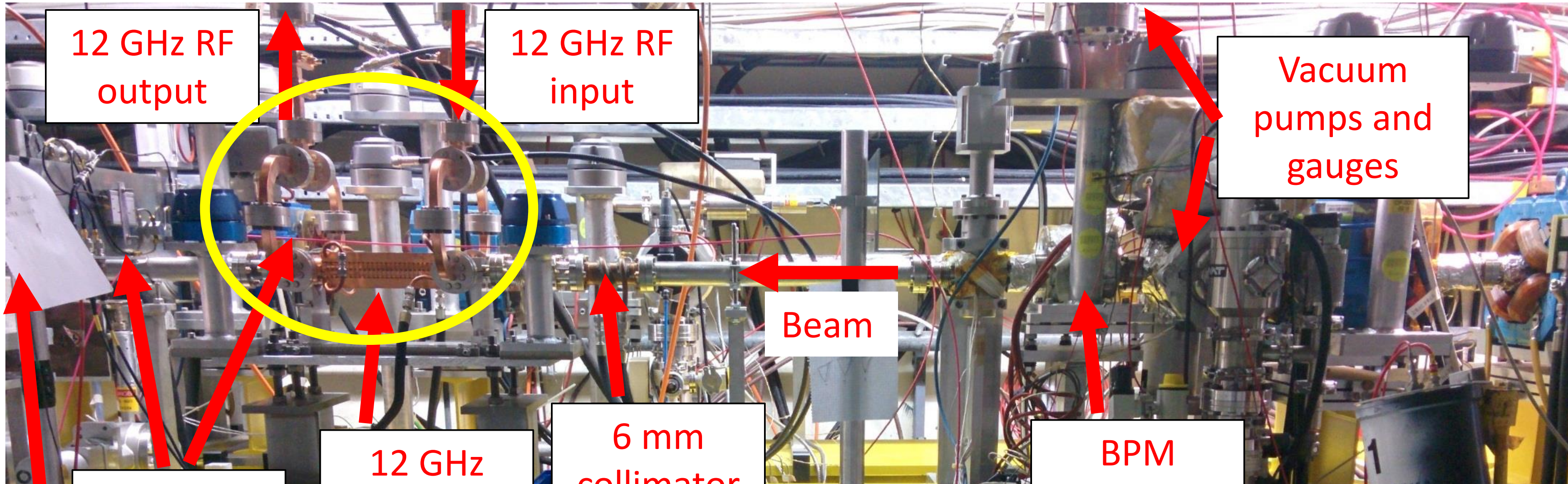




High-gradient performance summary



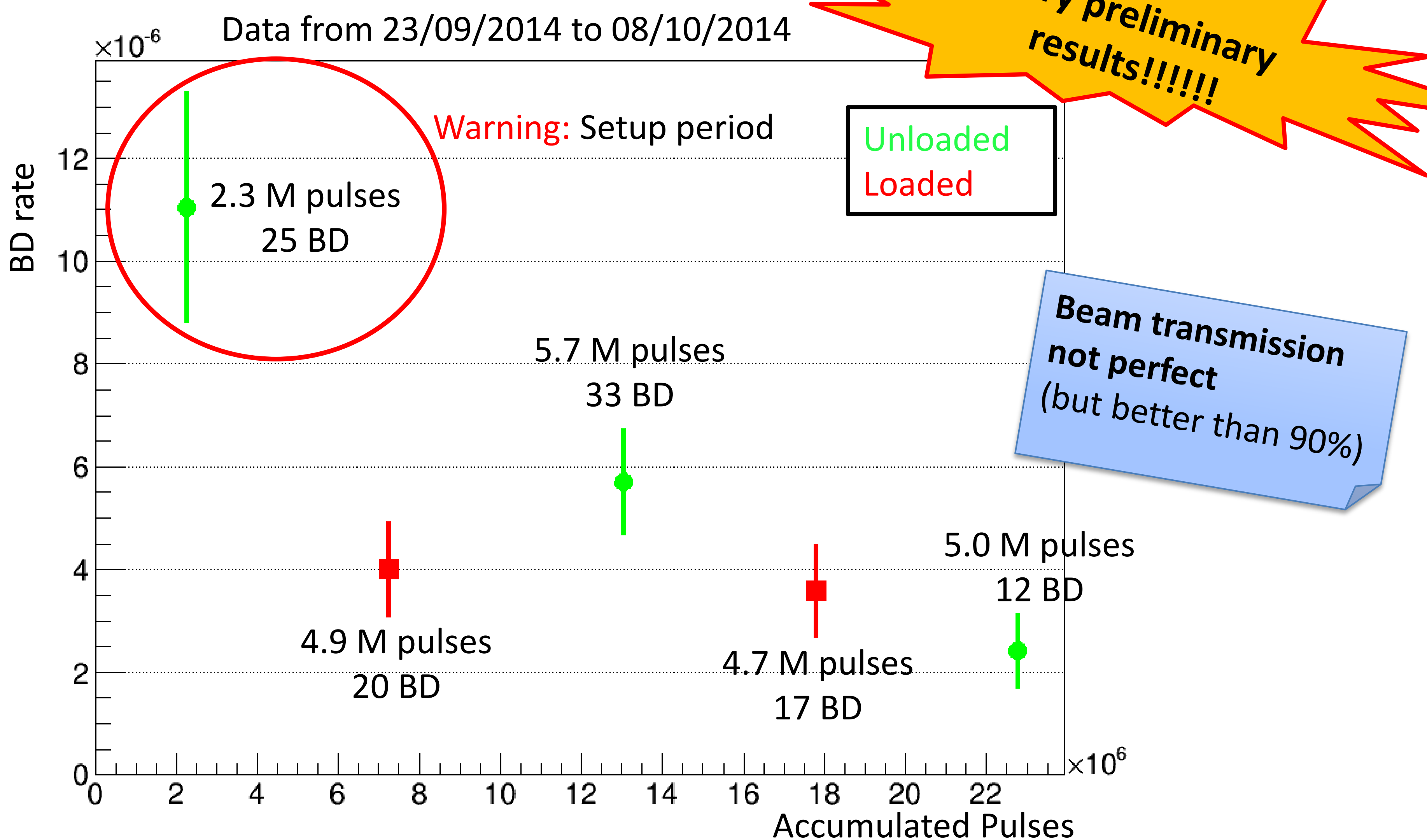
Diagnostic, control and protection



12 GHz accelerating structure surrounded by a complete set of instrumentation:

- 2 inductive BPMs (1 upstream and 1 downstream)
- 6 mm collimator to protect the structure
- Fibre optic and diamond beam loss monitors
- Vacuum pumps and gauges in beam chamber and RF waveguides

First Results: BDr



Preliminary Conclusion:

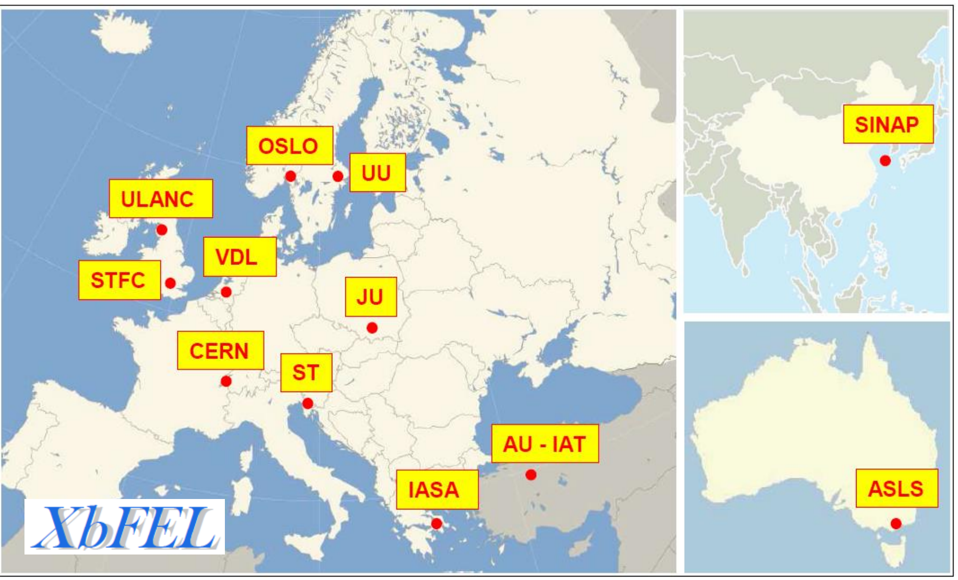
- Beam loading does **not show an increased breakdown rate** at constant input power

Elettra Sincrotrone Trieste

XbFEL Collaboration

XbFEL

XbFEL is a collaboration among several laboratories aimed at promoting the development of X-band technology for FEL based photon sources.



ST	*Elettra - Sincrotrone Trieste, Italy.*
CERN	*CERN Geneva, Switzerland.*
JU	*Jagiellonian University, Krakow, Poland.*
STFC	*Daresbury Laboratory Cockcroft Institute, Daresbury, UK*
SINAP	*Shangai Institute of Applied Physics, Shanghai, China.*
VDL	*VDL ETG T&D B.V., Eindhoven, Netherlands.*
OSLO	*University of Oslo, Norway.*
IASA	*National Technical University of Athens, Greece.*
UU	*Uppsala University, Uppsala, Sweden.*
ASLS	*Australian Synchrotron, Clayton, Australia.*
UA-IAT	*Institute of Accelerator Technologies, Ankara, Turkey.*
ULANC	*Lancaster University, Lancaster, UK.*

Elettra Sincrotrone Trieste · CERN · Jagiellonian University in Krakow · Science & Technology Facilities Council · SINAP · VDL

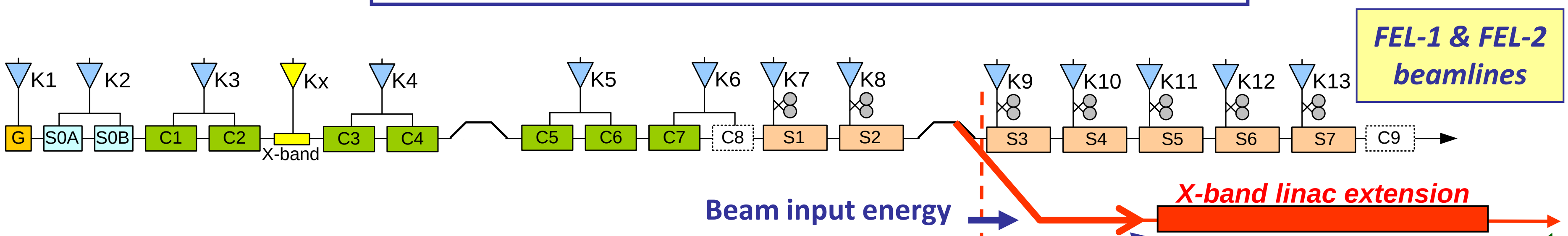
NTUA · IASA · Uppsala Universitet · Australian Synchrotron · Ankara Üniversitesi 1946 · Lancaster University

FERMI@Elettra: present layout and energy upgrade

Present layout and proposed energy upgrade

FERMI current layout and performance:

- ***E_{beam} up to 1.5 GeV***
- ***FEL-1 at 80-10 nm and FEL-2 at 10-4 nm***
- ***Seeded schemes***
- ***Long e-beam pulse (up to 700 fs), with "fresh bunch technique" for FEL-2***



Beam input energy
≥ 750 MeV

~50 m available

40 m (80%)
available for acceleration

X-band energy upgrade

• *Space available for acceleration*	*40 m*
• *Accelerating gradient @12 GHz*	*60 MV/m*
• *X-band linac energy gain*	*2.4 GeV*
• *Injection energy*	*.75 GeV*
• *Linac output energy*	*3.15 GeV*

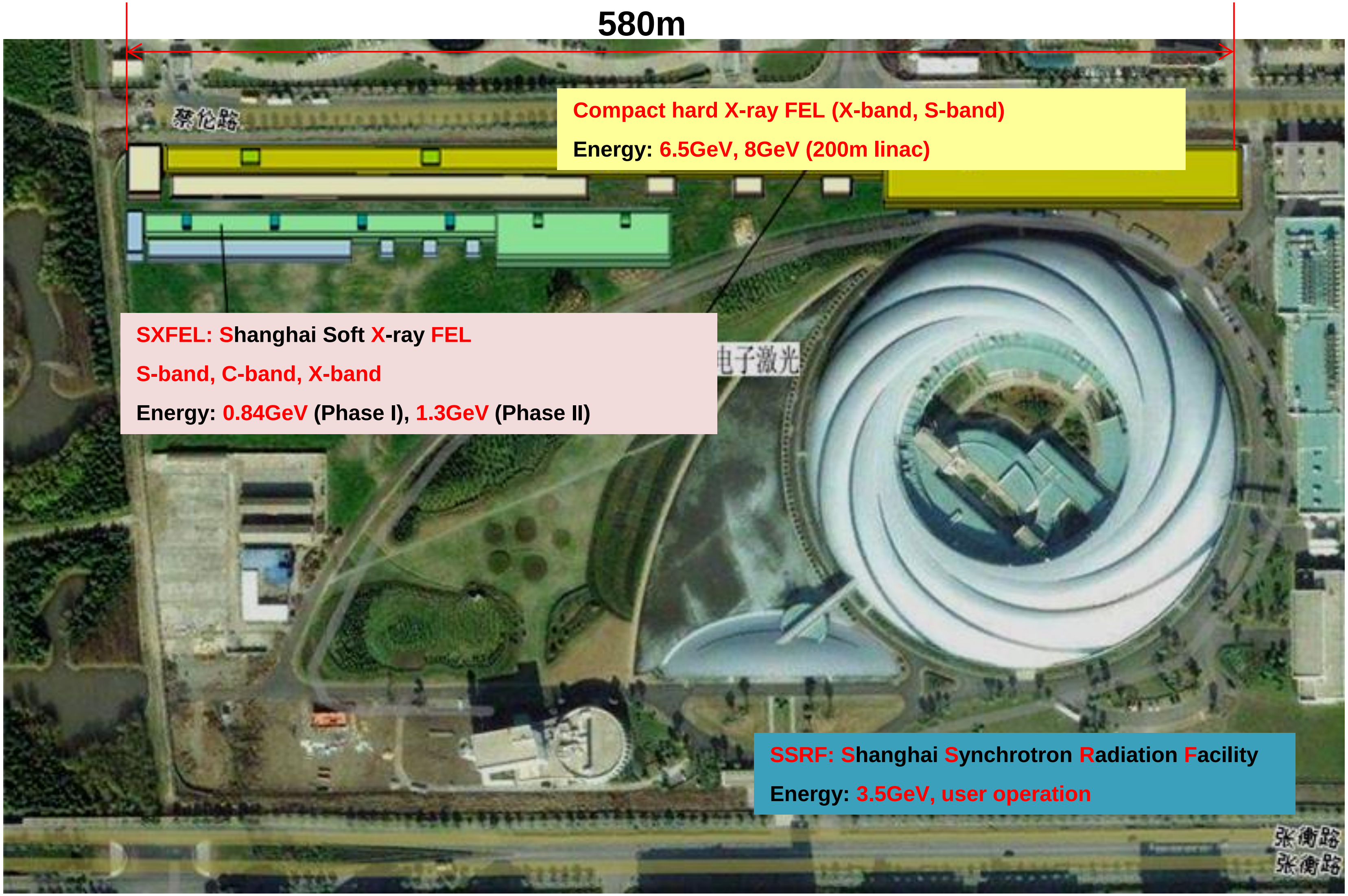
e-beam for a new FEL beamline

$\lambda \leq 1$ nm

Operation:

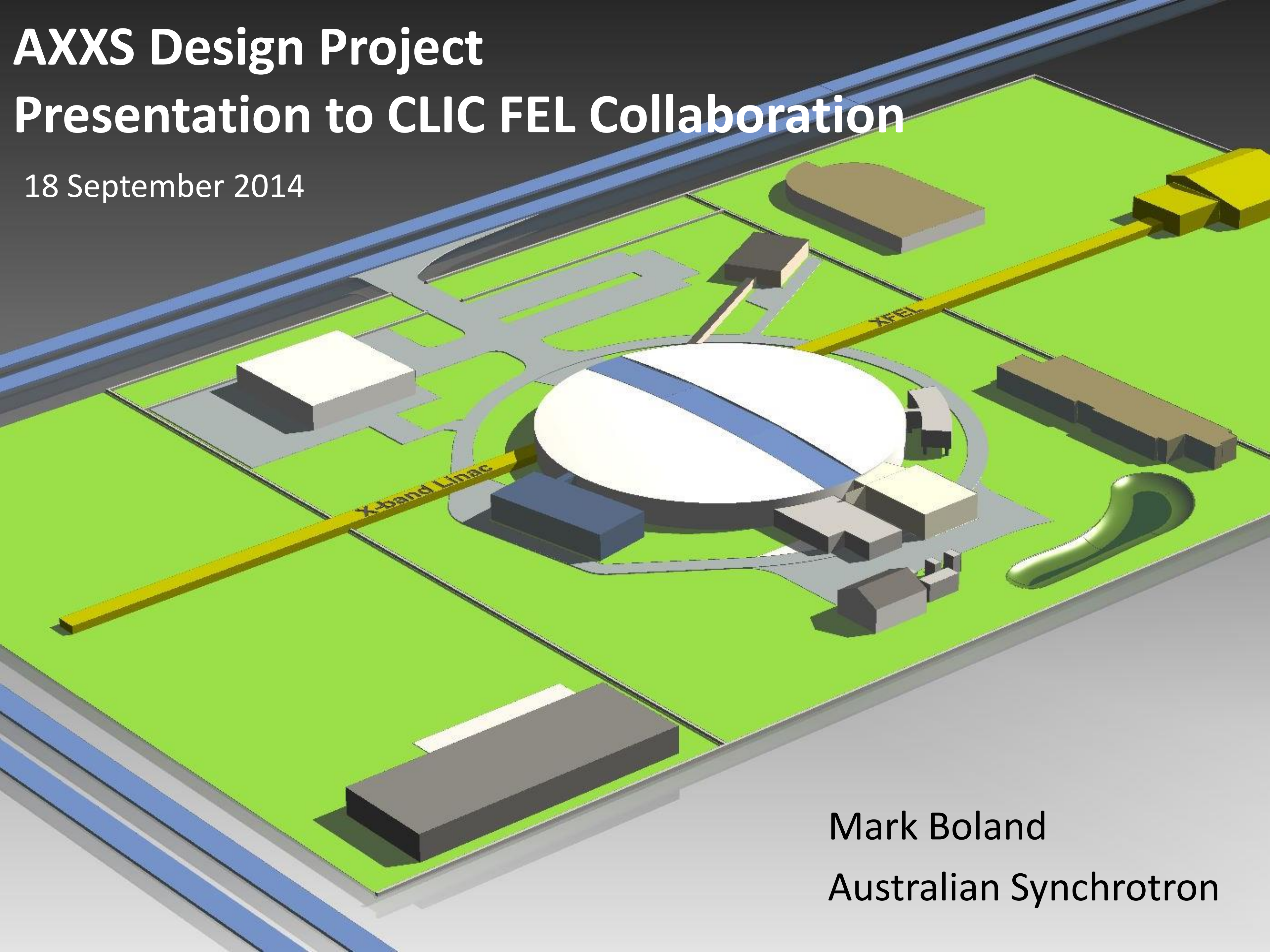
- *short bunch (< 100 fs)*
- *low charge (< 100pC)*

Shanghai Photon Science Center at SINAP



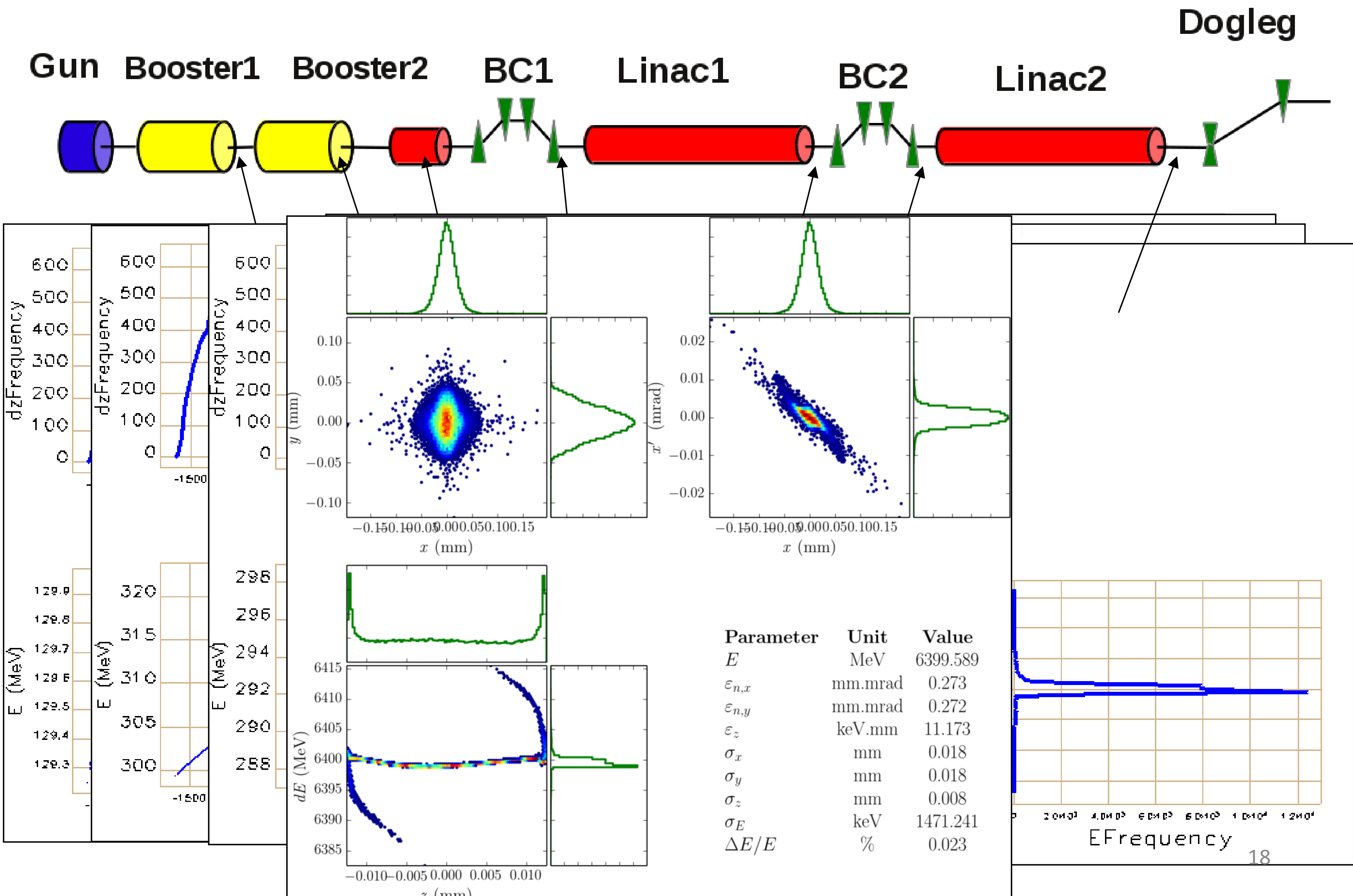
AXXS Design Project
Presentation to CLIC FEL Collaboration

18 September 2014



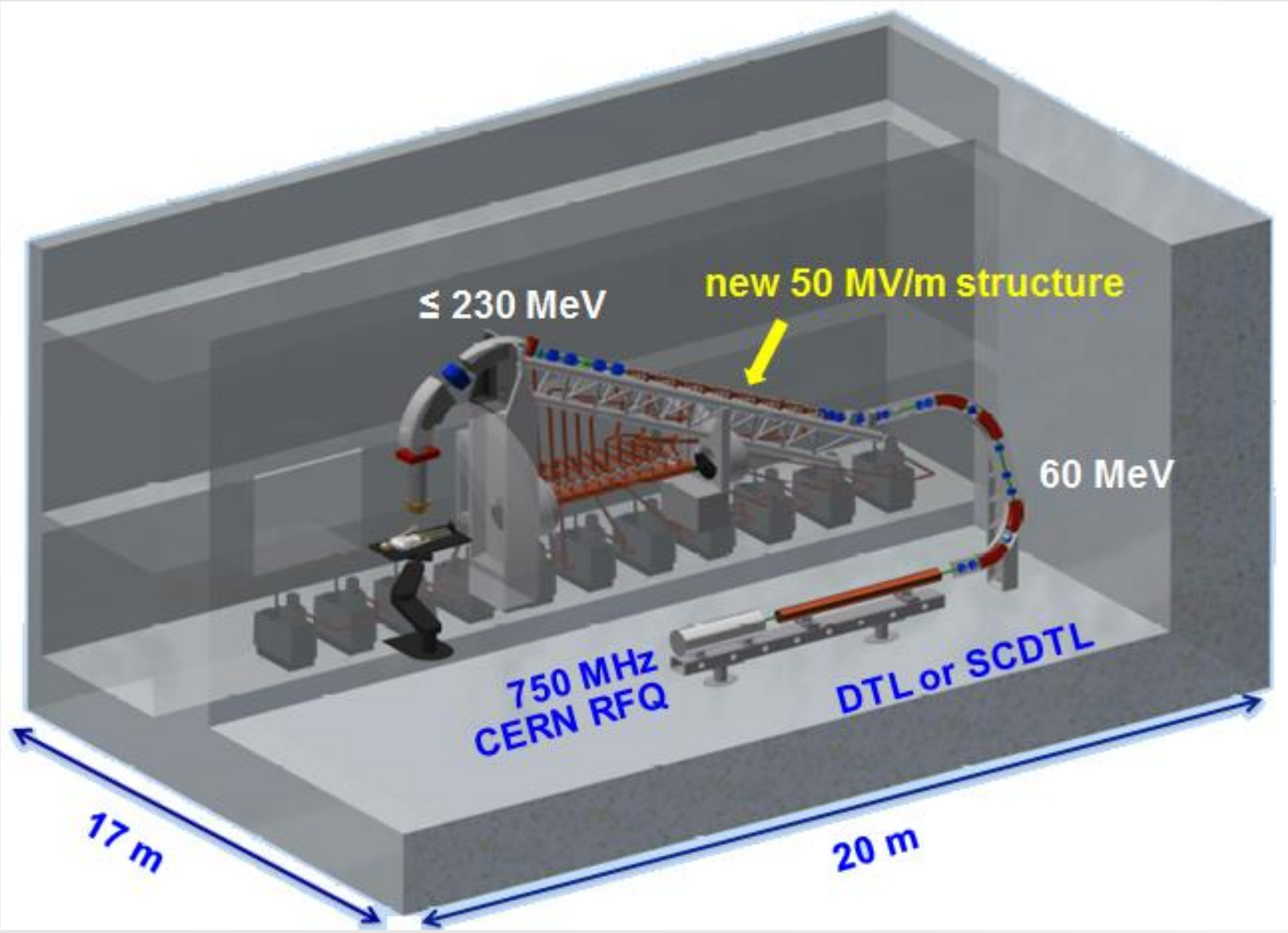
Mark Boland
Australian Synchrotron

Bunch compression



Parameter	Unit	Value
E	MeV	6399.589
$\varepsilon_{n,x}$	mm.mrad	0.273
$\varepsilon_{n,y}$	mm.mrad	0.272
ε_z	keV.mm	11.173
σ_x	mm	0.018
σ_y	mm	0.018
σ_z	mm	0.008
σ_E	keV	1471.241
$\Delta E/E$	%	0.023

A single room protontherapy facility has been designed by TERA Foundation at CERN in collaboration with the CLIC group.



A linac based proton therapy facility

Collaborative X-band and high-gradient structure production

Institute	Structure	Status
KEK	Long history – latest TD26CC	Mechanical design
Tsinghua	T24 - VDL machined, Tsinghua assembled, H bonding, KEK high-power test	At KEK
	CLIC choke	manufacturing tests
SINAP	XFEL structure, KEK high-power test	rf design phase
	T24, CERN high-power test	Agreement signed
	Four XFEL structures	H2020 proposal
CIEMAT	TD24CC	Agreement signed
PSI	Two T24 structures made at PSI using SwissFEL production line including vacuum brazing	Mechanical design work underway
VDL	XFEL structure	H2020 proposal
SLAC	T24 in milled halves	machining
CERN	see Anastasiya's talk	
	KT (Knowledge Transfer) funded medical linac	machining

State of art: L-band 10 MW MBK klystrons for ILC

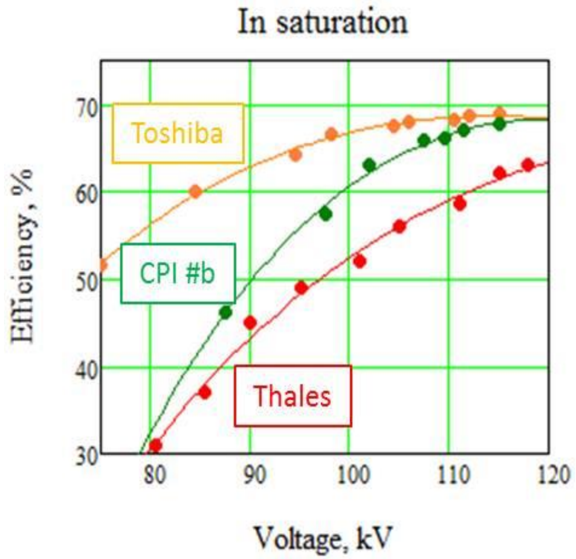
Thales

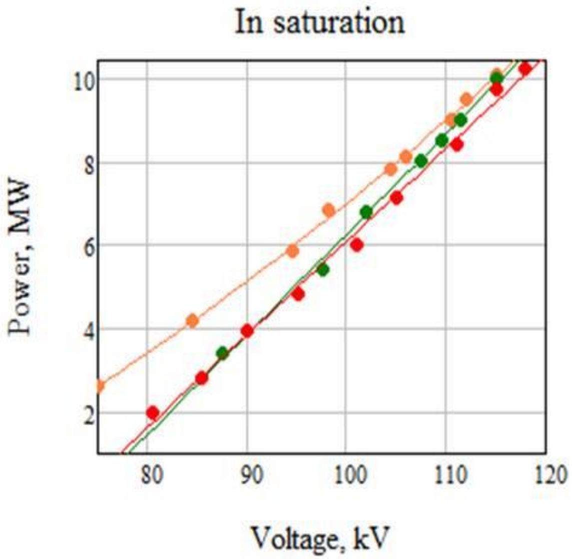
Toshiba

CPI #a

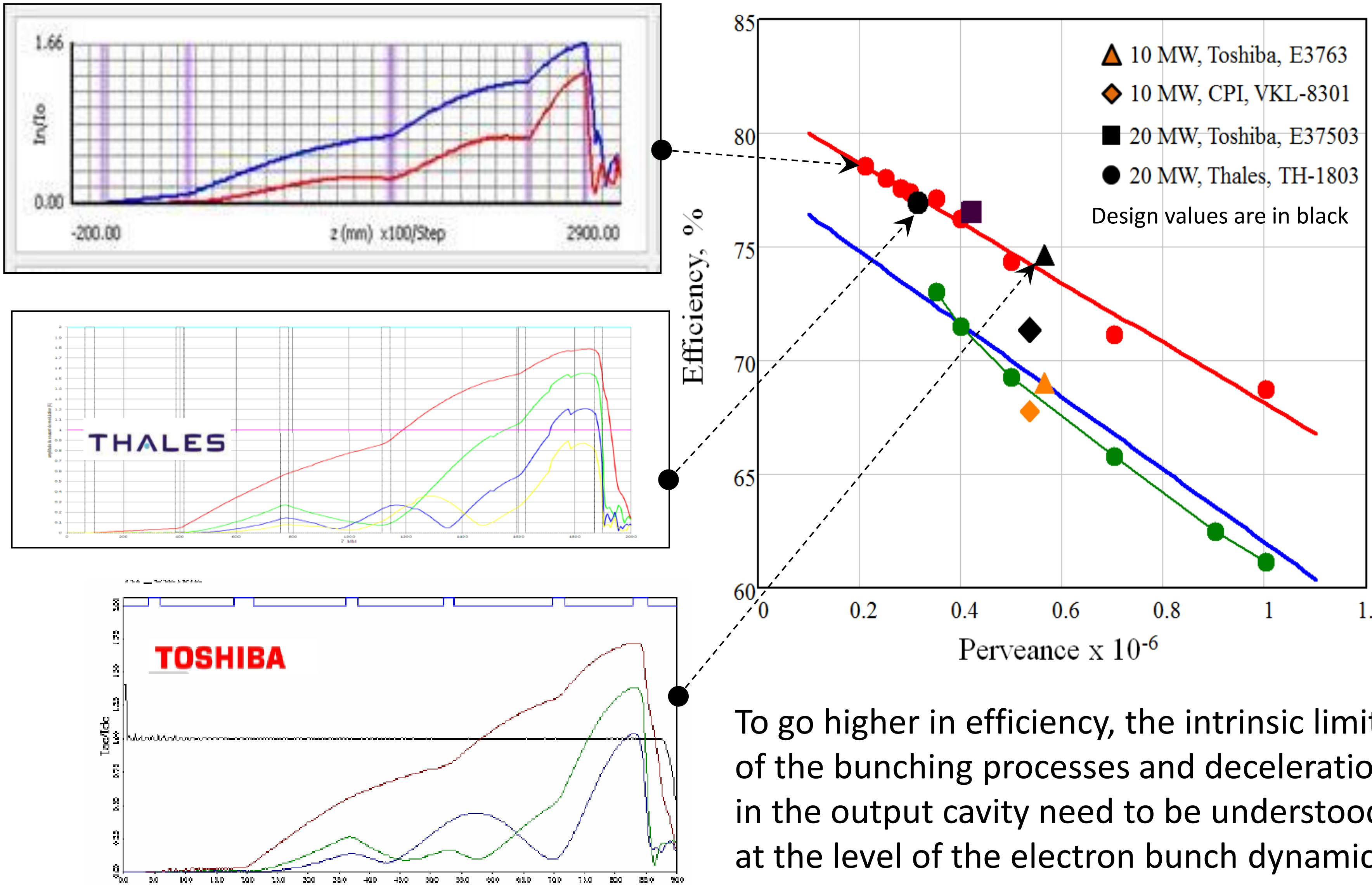
CPI #b

In terms of achieved efficiency at 10 MW peak RF power level, the existing MBK klystrons provides values very close to the 70%, as is specified in CLIC CDR.



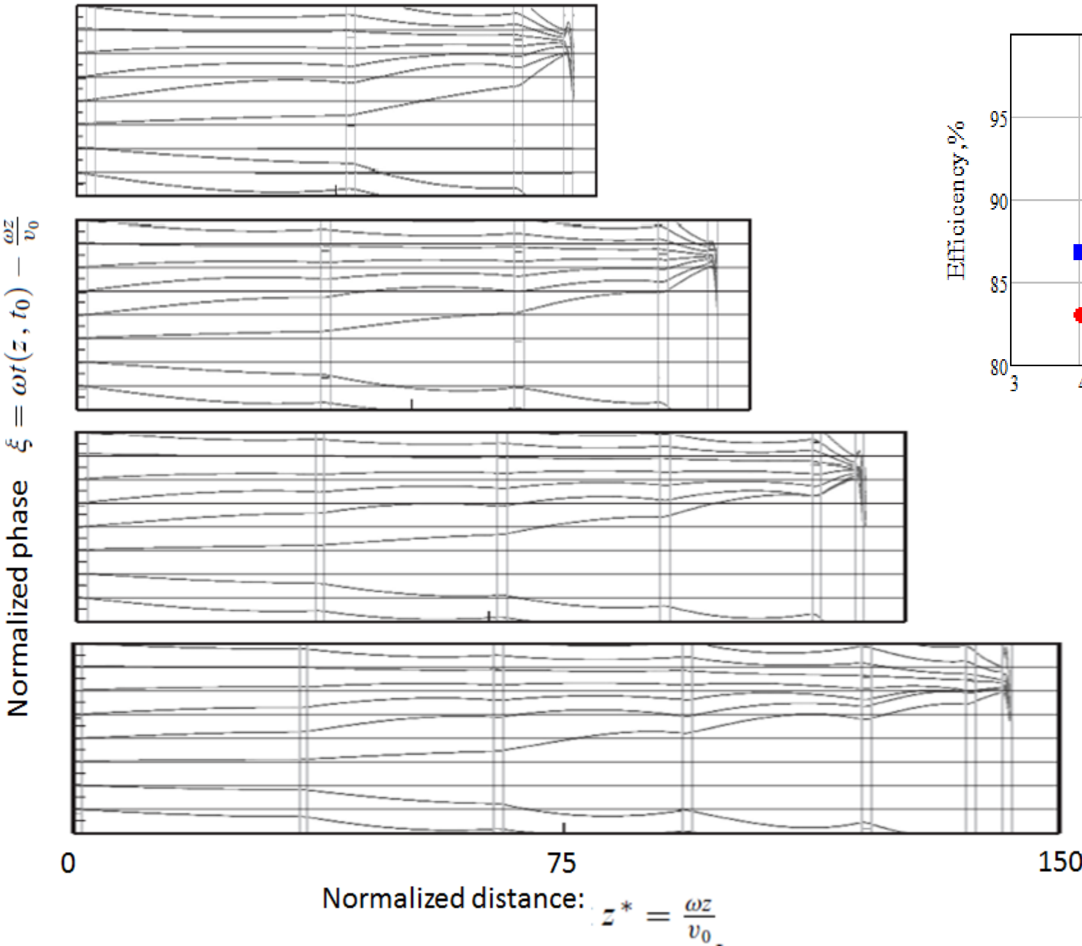


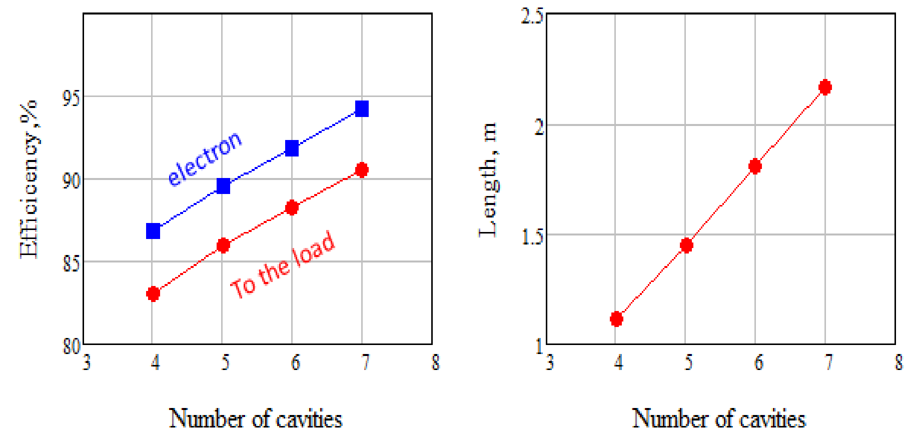
Scaling of the klystron parameters



To go higher in efficiency, the intrinsic limits of the bunching processes and deceleration in the output cavity need to be understood at the level of the electron bunch dynamic.

90% efficient klystron.





Simulation of Conditions for the Maximal Efficiency of Decimeter-Wave Klystrons

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Received May 14, 2013

To achieve very high efficiency, peripheral electrons should receive much stronger relative phase shift than the core electrons and this could happens only, if the **core** of the bunch experiences **oscillations** due to the space charge forces, whilst the peripherals approach the bunch centre monotonously.

High efficiency – high perveance Klystron (X-band)

EnEfficiency RF sources Workshop

Cockcroft Institute

Franck Peauger
CEA/IRFU/SACM/LISAH

June 3, 2014

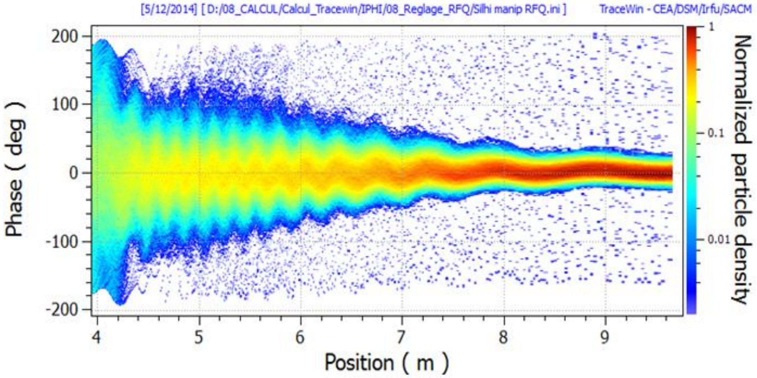
- A system is called adiabatic when the external forces vary more slowly than the interaction forces in the system. The dynamics of the system is then a **succession of equilibrium states** and the entropy does not increase.
  - In our case, the external forces are the beam induced bunching forces and the interaction forces are the space charge forces.

The bunching process in an RFQ is adiabatic (« gentle » buncher)

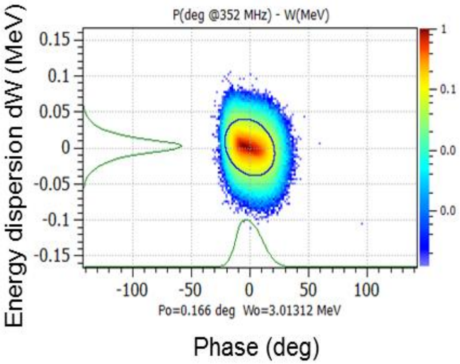
The RFQ preserve the beam quality, has a high capture (~90%) compare to a discrete bunching model (50%)

In the IPHI RFQ (3 MeV, 6m, 352 MHz), around 350 cells are used to bunch the beam

Along the 6m RFQ:



At the RFQ exit:



Link: https://indico.cern.ch/event/297025/

Strategy for high-efficiency high RF power klystron development