

IFIC
INSTITUT DE FÍSICA
CORPUSCULAR



VNIVERSITAT
ID VALÈNCIA



CSIC

CONSEJO SUPERIOR DE INVESTIGACIONES CIENTÍFICAS



High-gradient results at CERN I

Anna Vnuchenko

on Behalf of the Xbox Team
Univ. of Valencia and CSIC (ES)

CLIC Workshop
22nd January 2018





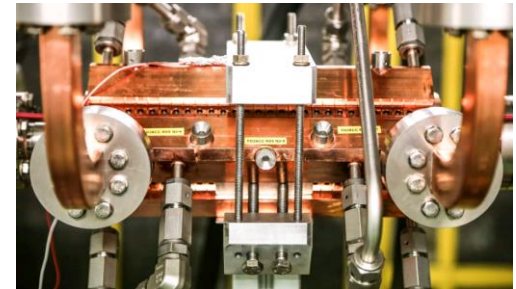
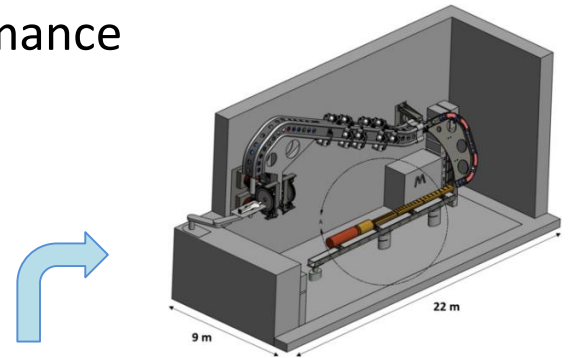
Outline

- ❑ Main testing objectives
- ❑ Overview of testing facilities
- ❑ High power testing of CLIC AS prototypes
- ❑ Conditioning progress of the structure under test
- ❑ Conclusions and next steps



Main testing objectives:

- A comparative study of the structure performance
- Implementation new technology
- To gain operational experience
- Statistics improvement
- Long term operation





Overview of testing facilities

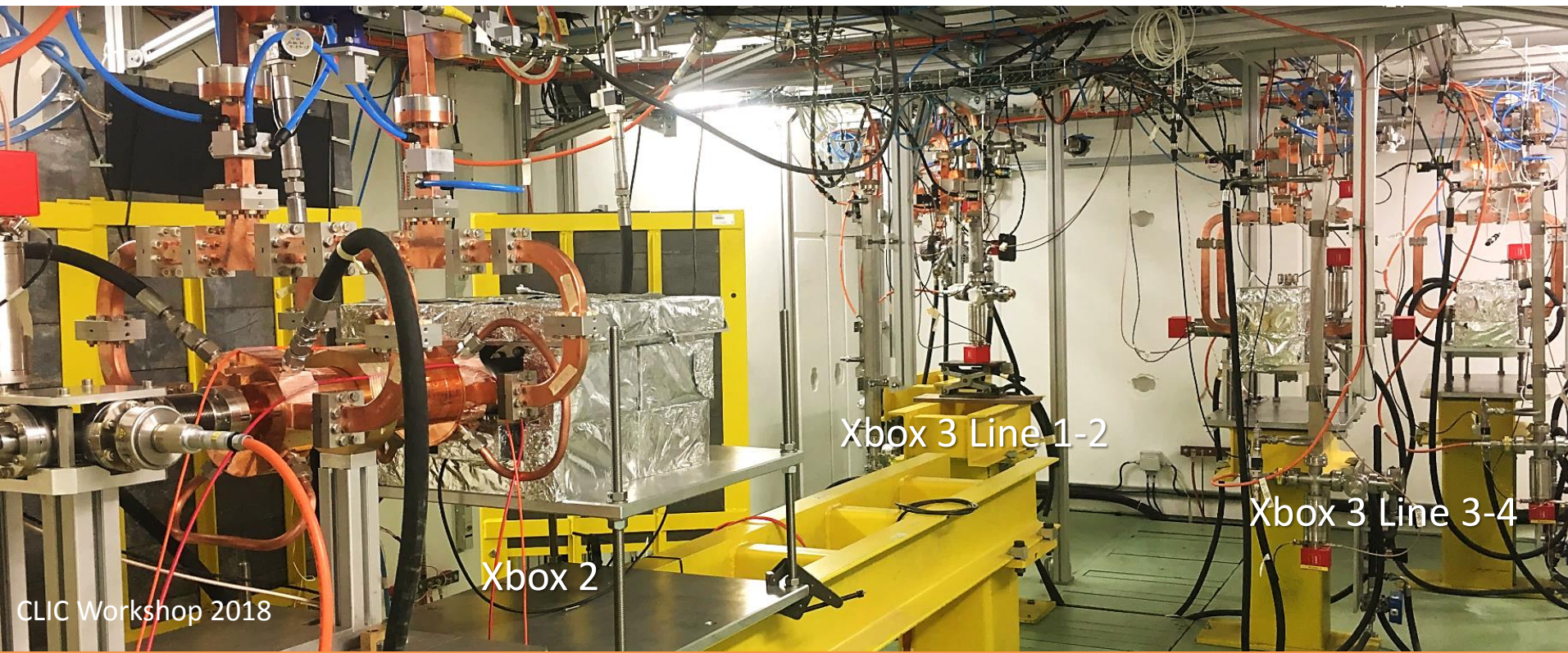
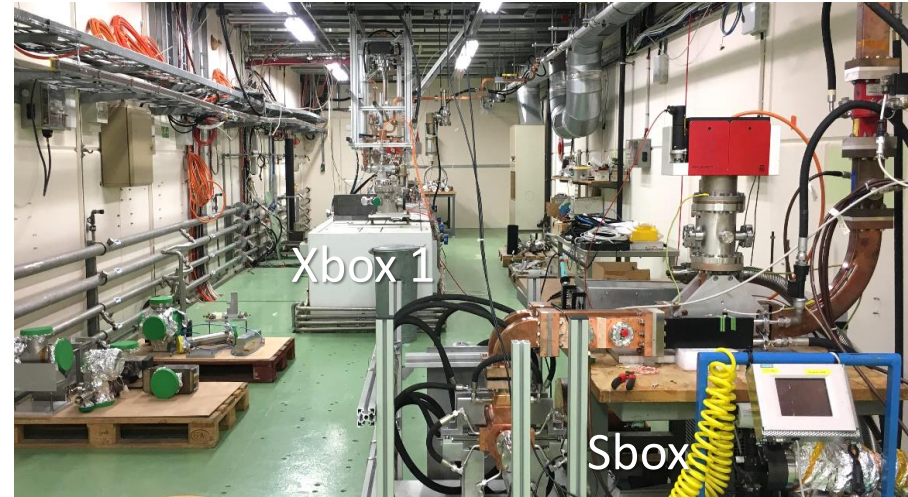
Klystron-based test stands at CERN:

❑ **11.994 GHz, X-band:**

Xbox 1 - 2: 50 MW klystron, 50 Hz,

Xbox 3: 4x6 MW klystrons, 50 - 400 Hz,
4 structure test slots.

❑ **2.9985 GHz, S-band, 25Hz (Sbox).**

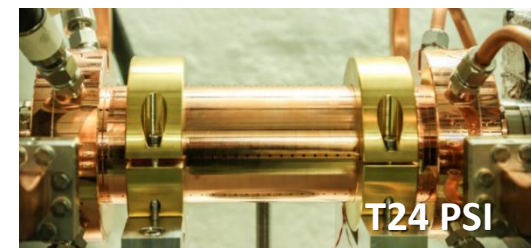
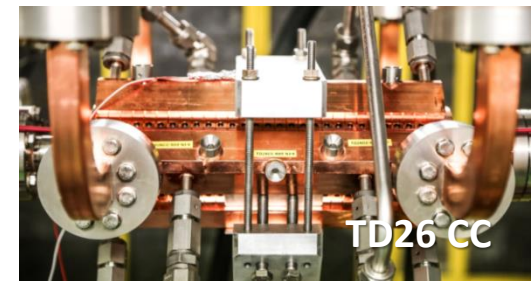




High Power testing of AS prototypes

Five structures with 4 different designs currently under test at CERN:

- TD26CC R05 N2 (Xbox1)
- T24 PSI N1 (Xbox2):
- TD24 SIC N2 (Xbox3 Line 3)
- T24 PSI N2 (Xbox3 Line 4)
- 3 GHz BTW N1 (Sbox)

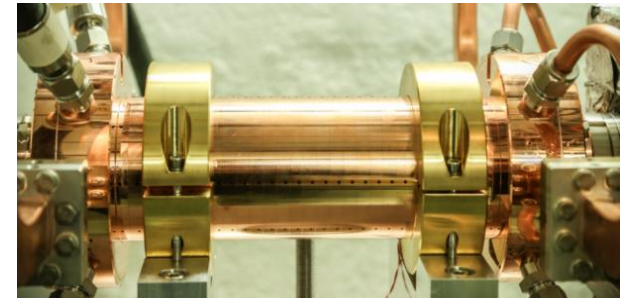


Conditioning status: T24 PSI N1 and N2

Undamped structure shows best performance up to now.

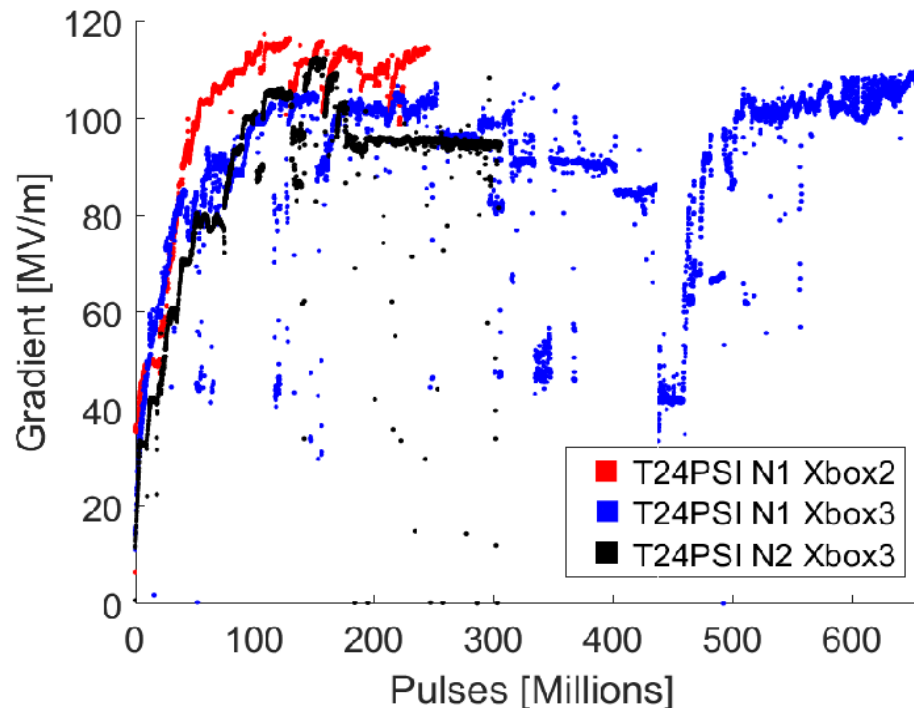
❑ T24 PSI N1:

- ✓ previously tested structures at Xbox3
- ✓ gradient about 110 MV/m for 200 ns
- ✓ moved to Xbox 2 => **118 MV/m at 200 ns**



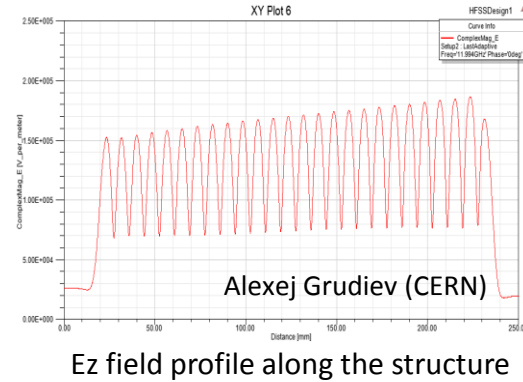
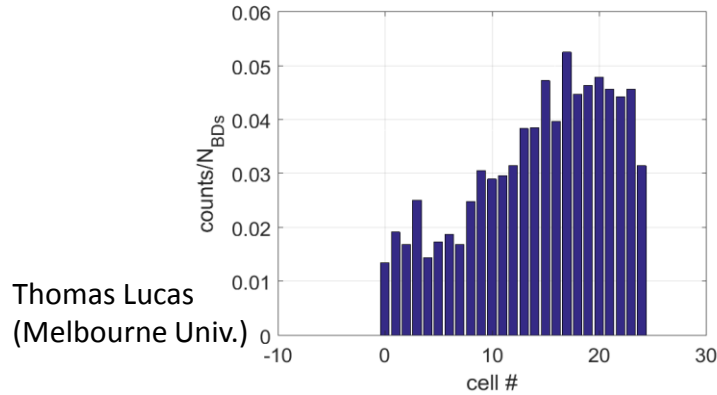
❑ T24 PSI N2:

- ✓ test at Xbox 3: gradient above 110 MV/m

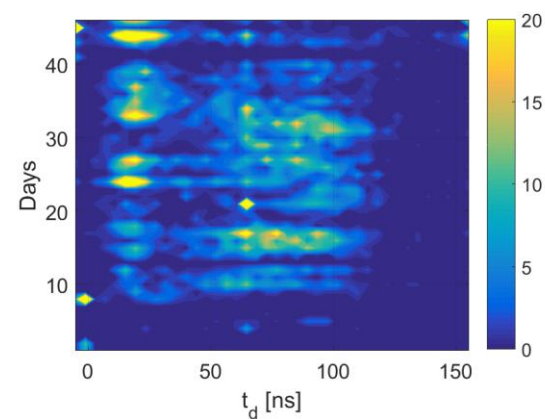
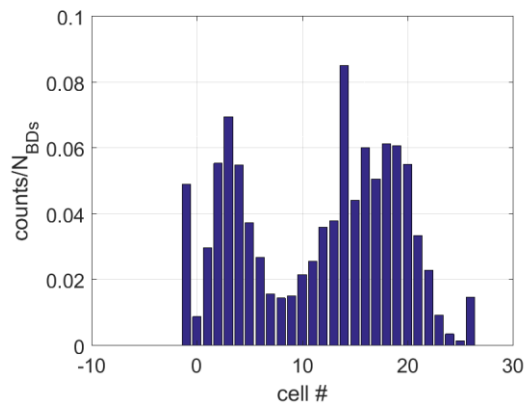


Conditioning status of T24 PSI N1

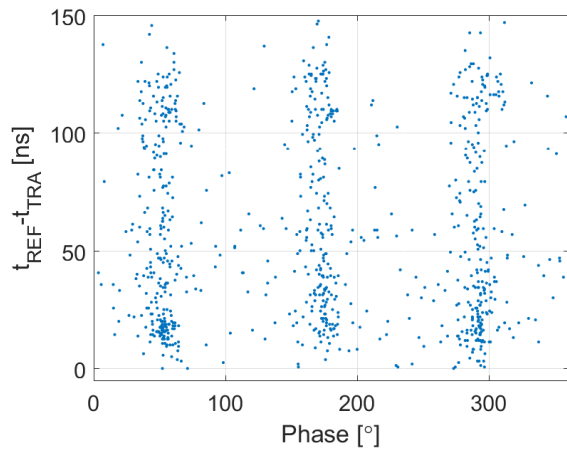
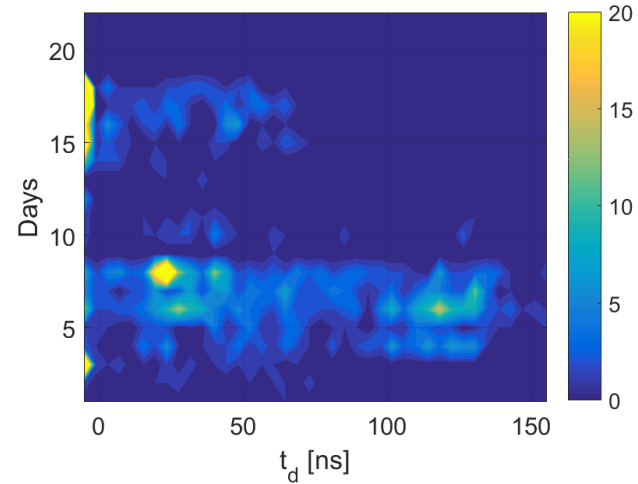
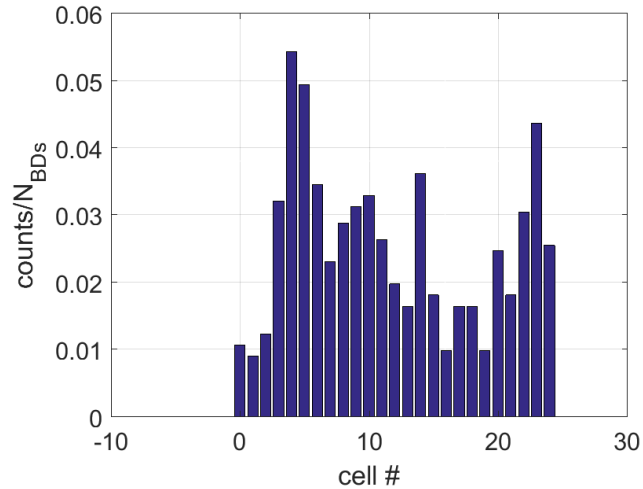
- **The previous test:** BD distribution increases along the structure following the field distribution.



- **The current test:**



Conditioning status of T24 PSI N2

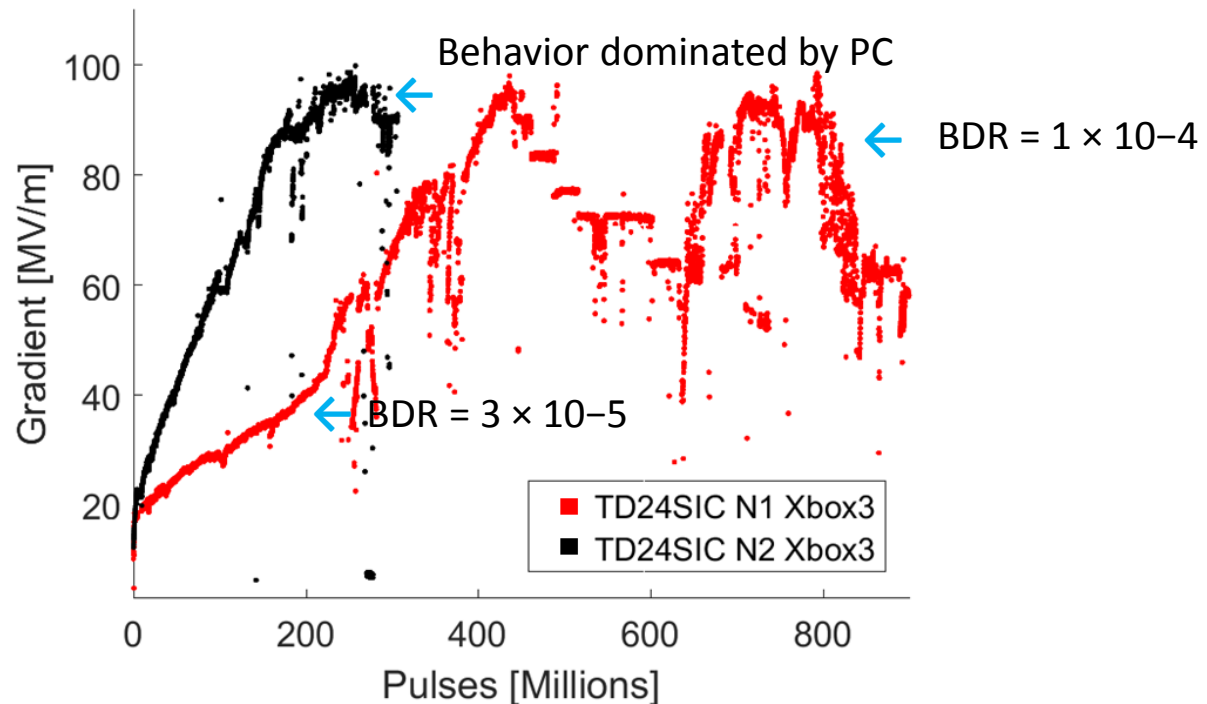


- Phase distribution of the BDs spaced by 120 degrees.
- Combination of timing and phase information gives better accuracy in breakdown localization.

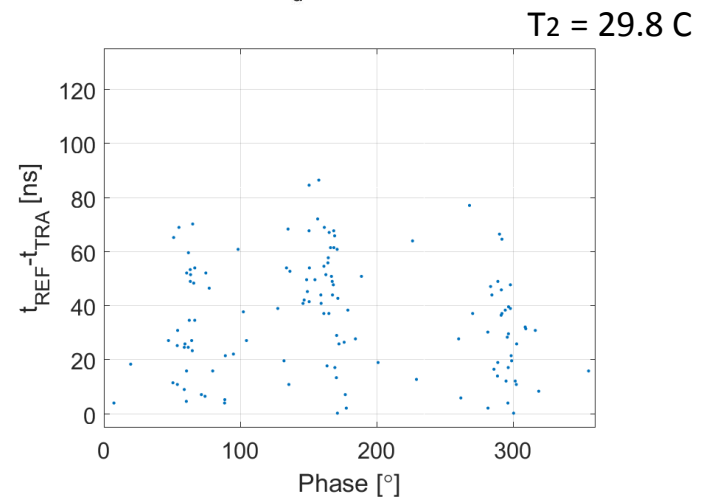
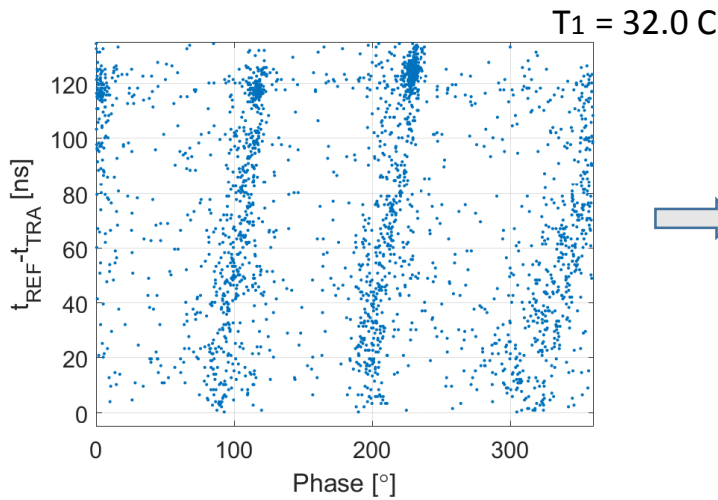
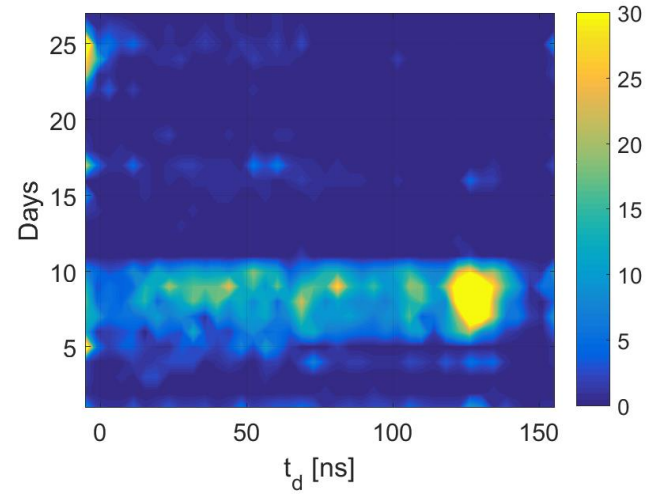
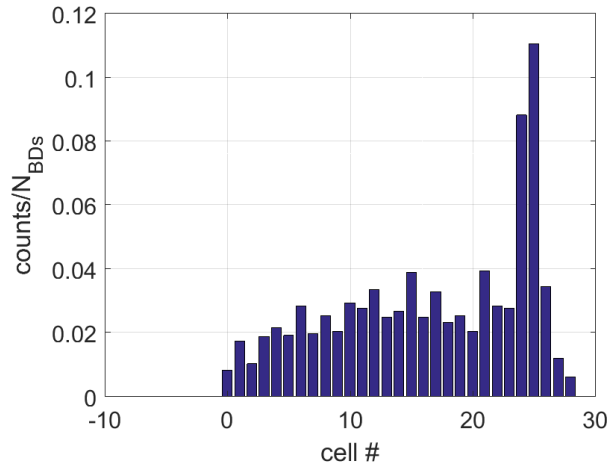
Conditioning behavior: TD24 SiC N1 and N2

Description: Silicon Carbide accelerating structure (TD24 with HOM damping material).

- ❑ **TD 24 SiC N1** was lost due to operation issue:
 - post-mortem analysis will be carried out.
- ❑ **TD 24 SiC N2:** no evidence of hot spot; gradient around **97 MV/m** at 50ns pulse.



Conditioning status of TD24 SiC N2

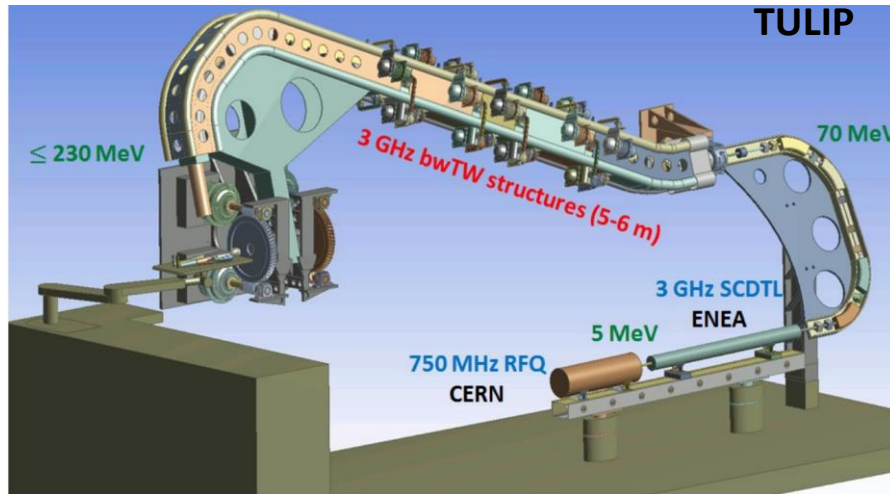


➤ Indicates the detuning of the structure



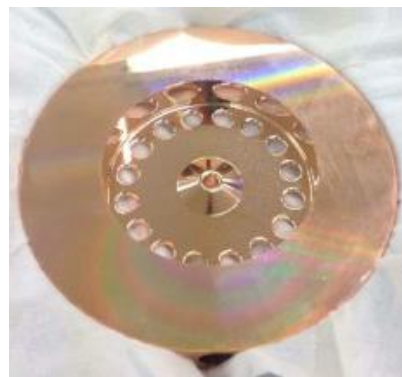
Conditioning status of HG medical linac structure

- ❑ Backward Travelling Wave (BTW) structure tested at Sbox since November 2016.

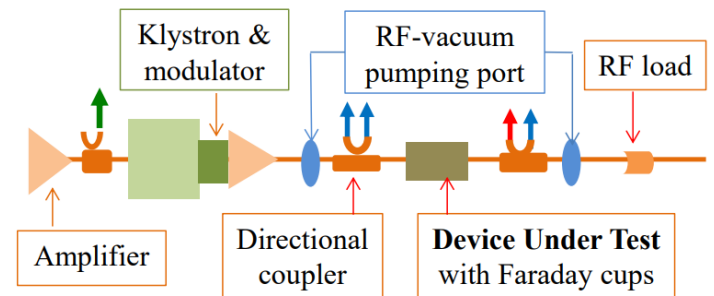


TURning Linac for Protontherapy

Number of RF cells	12
RF phase adv.	150 deg
Total length	189.84 mm
Max Es/Ea	3.9
Filling time	220 ns
Group velocity (1st/last)	0.39 / 0.21 %c



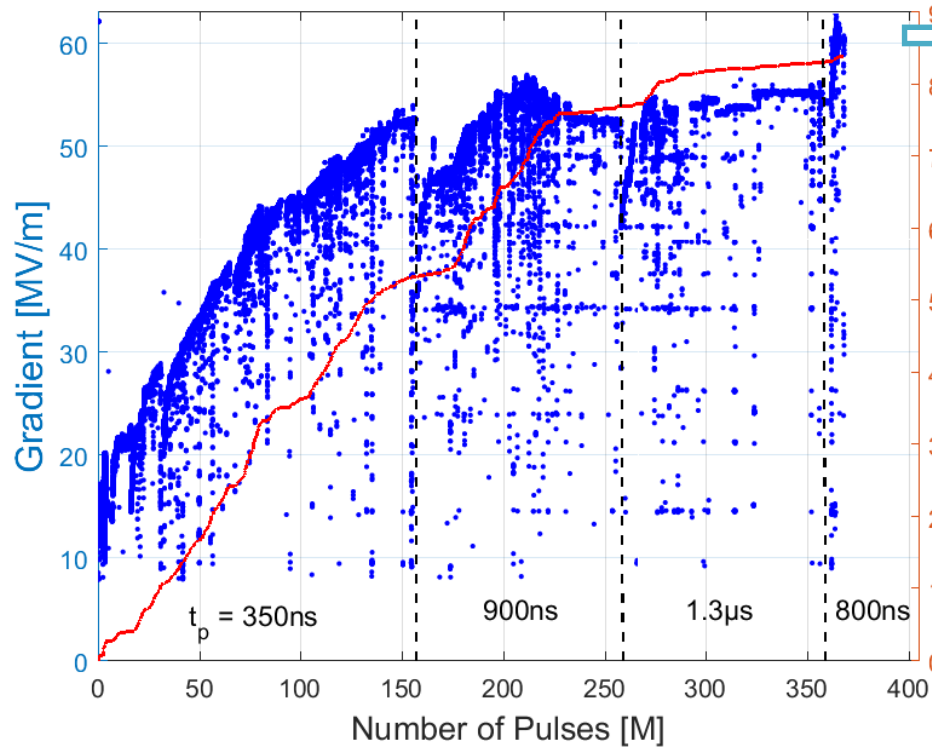
The 3 GHz BTW prototype



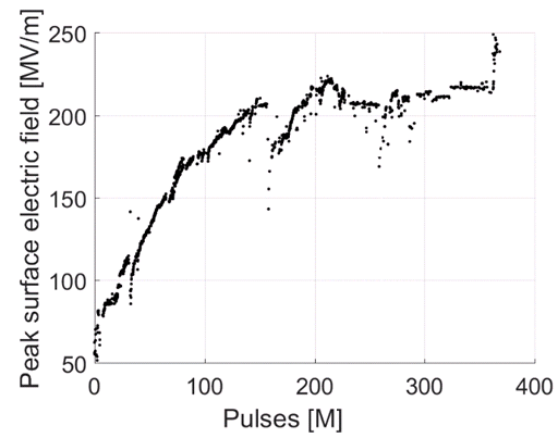
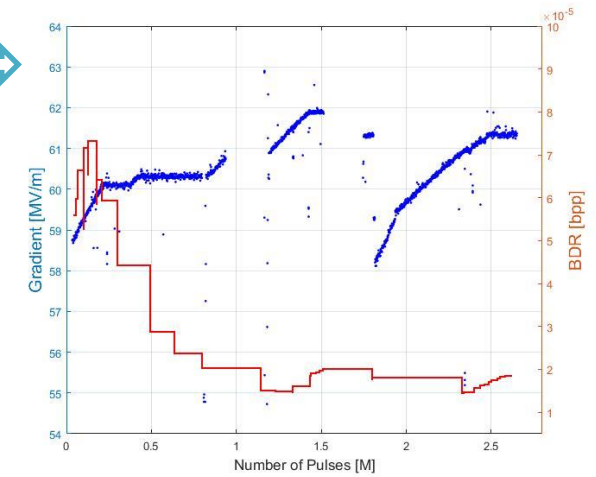
Functional diagram of S-band test facility



Conditioning status of 3GHz BTW



Number of BDs [$\cdot 10^3$]



Pulse width, ns	350	900	1300	800
Gradient, MV/m	52	55.6	54	62

Very high surface electric fields, over 200 MV/m

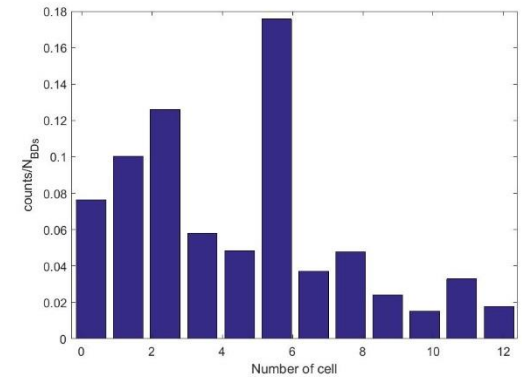
Tested to maximum power available and well over initial specifications.
Testing continues after switching to a new klystron with more potential power.



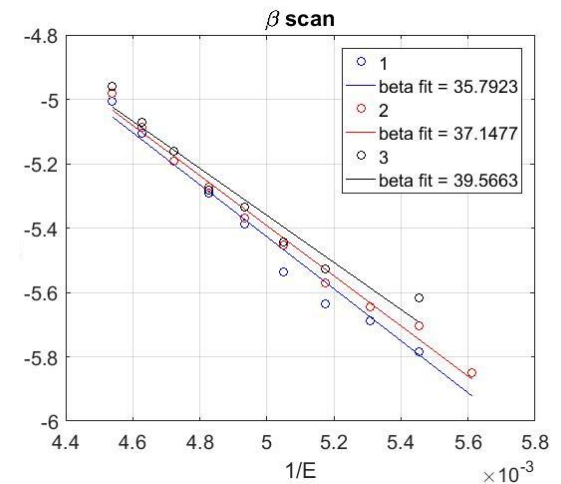
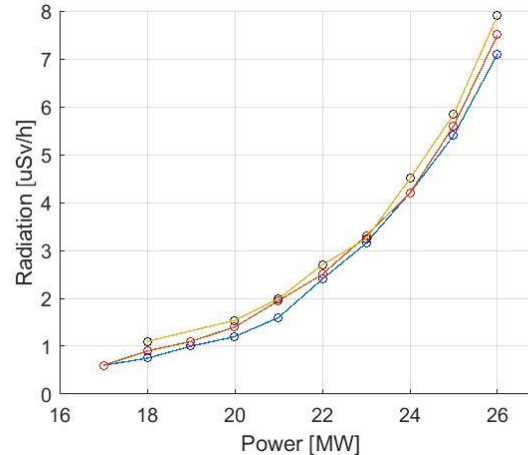
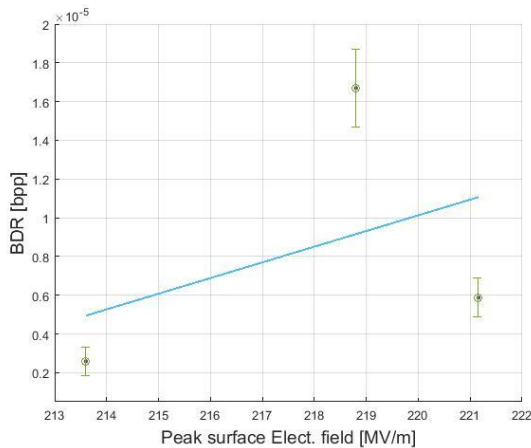
Conditioning status of 3 GHz BTW

High-gradient physics studies:

- RF conditioning,
- BD localisation,
- Dependence of BDR on field,
- Dark current measurements (change over time).



Dark current is measured by Faraday cups and Radiation Monitors.



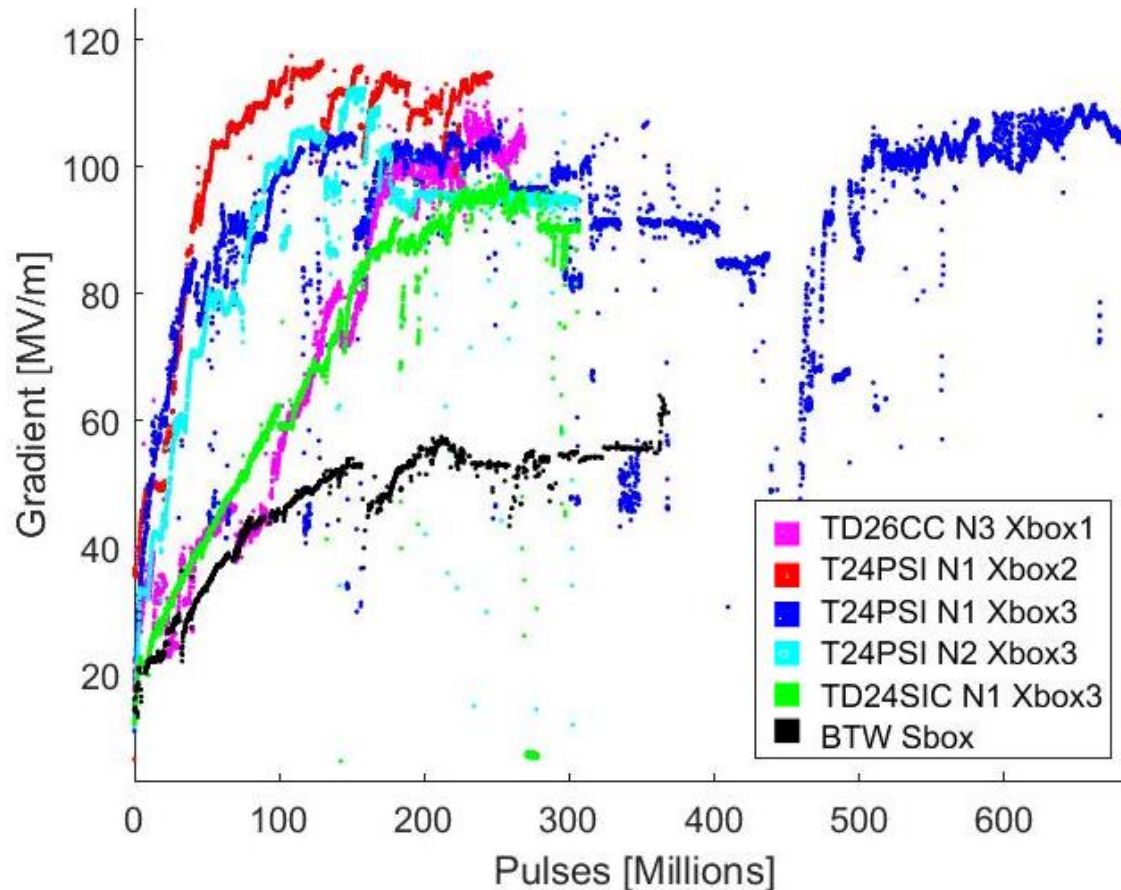
Dependence BDR vs E_{surf} : many interruptions due to instability of the modulator which have possible impact on the statistics.

Field enhancement factor $\beta = 35-40$.



Comparison of the conditioning vs. gradient

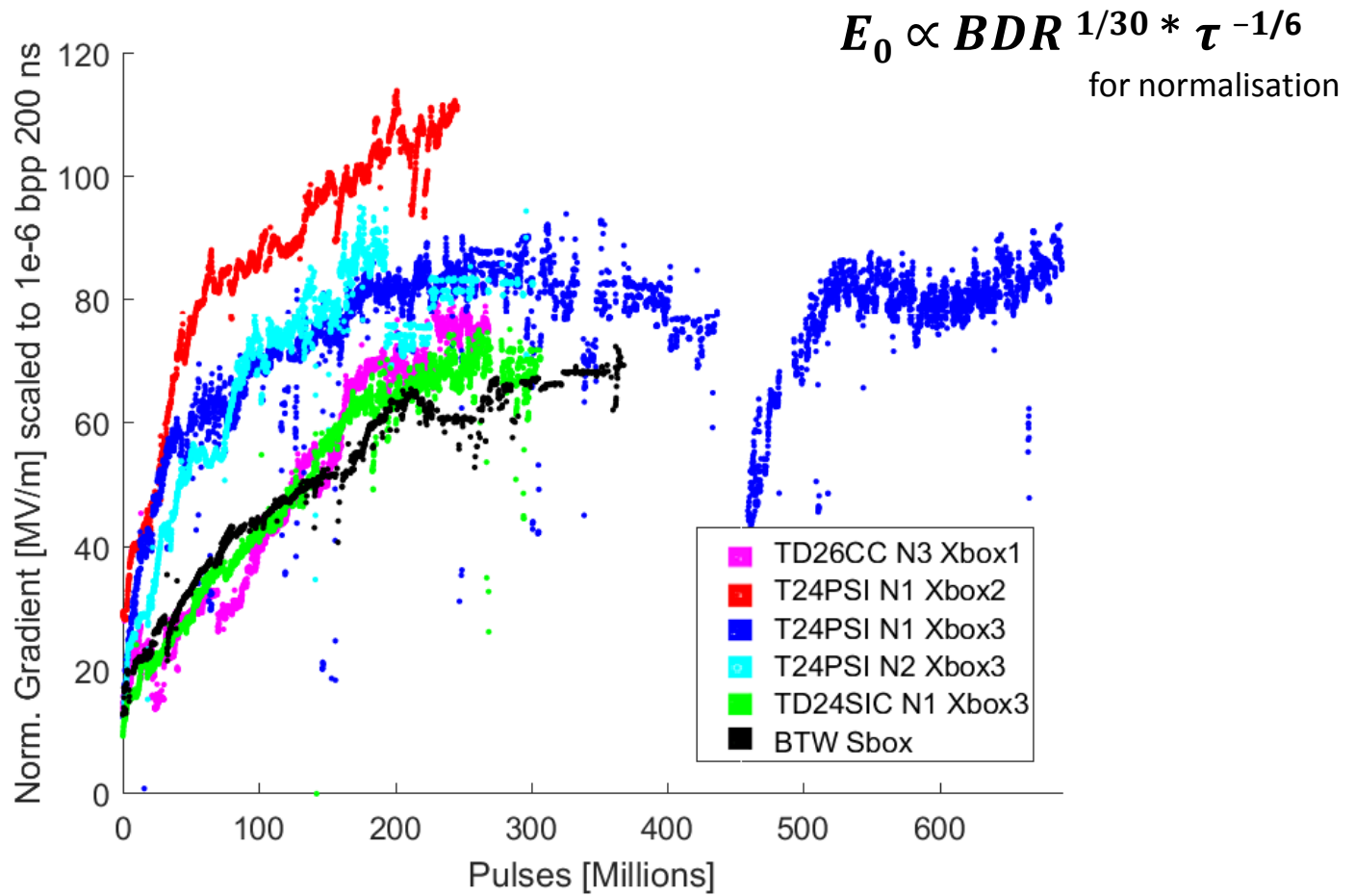
- Conditioning algorithm strongly affects the conditioning progress.



Comparison of the gradient of different prototypes tested at CERN.



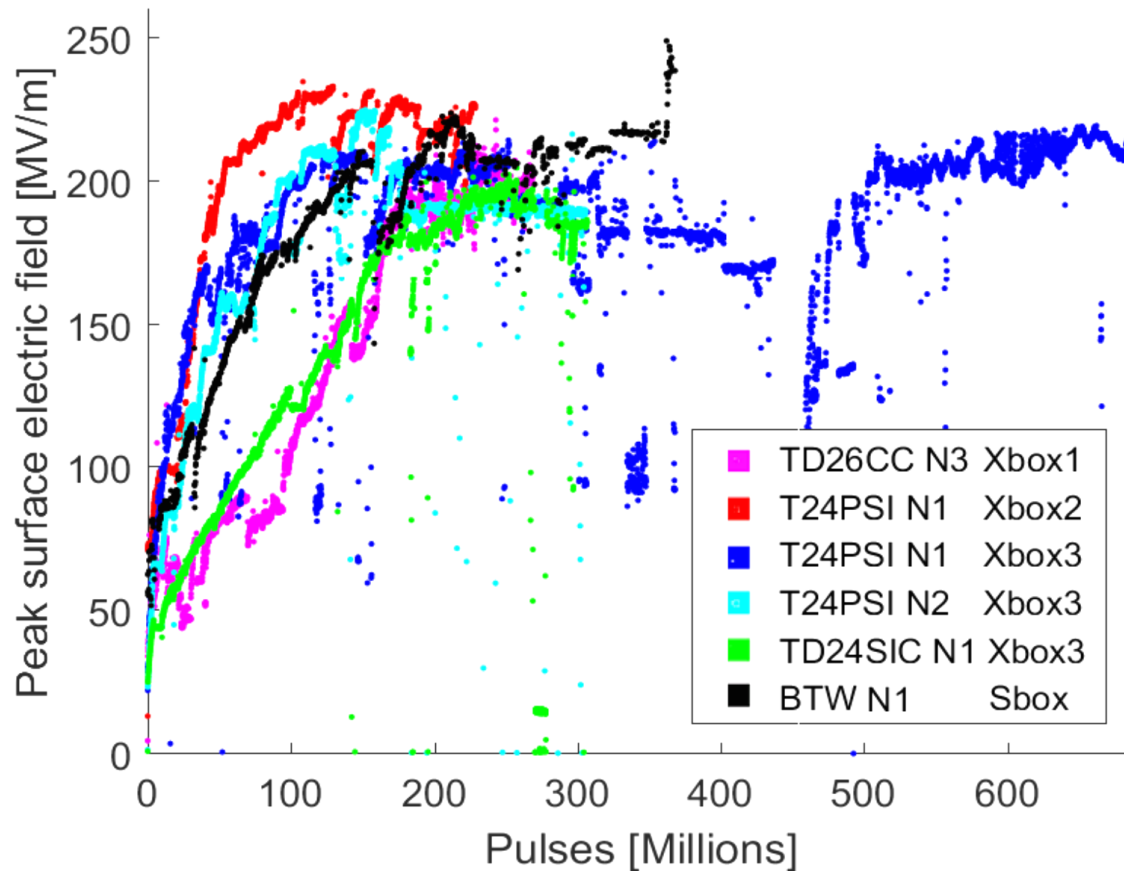
Comparison of the conditioning vs. normalized gradient





Comparison of the conditioning vs. the E_{surf}

The surface electric field is presented in comparison with CLIC structures ($E_s/E_c \approx 2$) and BTW ($E_s/E_c = 3.9$).





Conclusions

- ❑ Five structures with 4 different designs currently under test at CERN.
- ❑ Gradient of the acceleration structures above 100 MV/m, S band - 60 MV/m.
 - Xbox 1** continues HG test for better statistics of TD26CC.
 - Xbox 3 line 3-4** is used to preconditioning of the acc. structures
 - Xbox 2**: high power test
 - Xbox 3 line 1-2** is used to test components (3D loads) at this moment.
- ❑ Conditioning algorithms strongly influence the conditioning progress.
- ❑ **T24PSI N1** reaches **118 MV/M** at 200 ns.



What is next?

- ❑ Complete the testing of the structures and components that are currently being tested.
- ❑ Continue test dependence pulse length vs. BDR.

	Current test	Next test	Next ...
Xbox 1	TD26 PSI N2	To be continued	Test with beam from CLEAR
Xbox 2	T24 PSI N1	T24 PSI N2	TD26_SiC superstructure
Xbox 3 Line 1	3D-printed Spiral load	Power Splitter	Change klystron and test TD26R1 structures
Line 2	3D-printed Compact load	Phase Shifter	
Line 3	TD24 R05 SIC N2	Change PC	Unbaked/Baked TD24
Line 4	T24 PSI N2	TD24 R05 SIC N2	



Thank you for your attention!





Thank you for your attention!

