Argonne NATIONAL LABORATORY

# 75 MeV High Charge, Short Electron Bunches for the High Power High Frequency RF Generation and High Gradient Acceleration at Argonne

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**(for the AWA group and Euclid Techlab)**

**KEK 2012 HG workshop**

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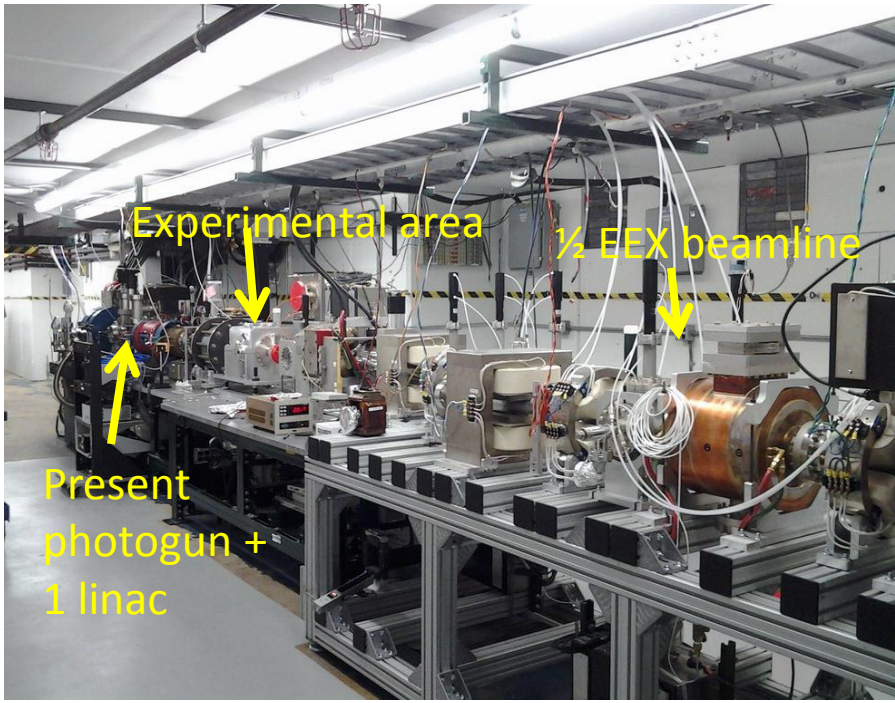
U.S. DEPARTMENT OF ENERGY

# AWA Facility - Present operation: 15 MeV Beam

## Basic parameters:

- 1.3GHz Photogun w/ Mg cathode
- 15 MeV, 1 – 100 nC (reached 150 nC)
- 2 mm bunch length
- norm emittance < 200 mm mrad (at 100 nC)
- High Current: ~ 10 kA
- Bunch train operation: 4 X 25nC or 16 X 5nC



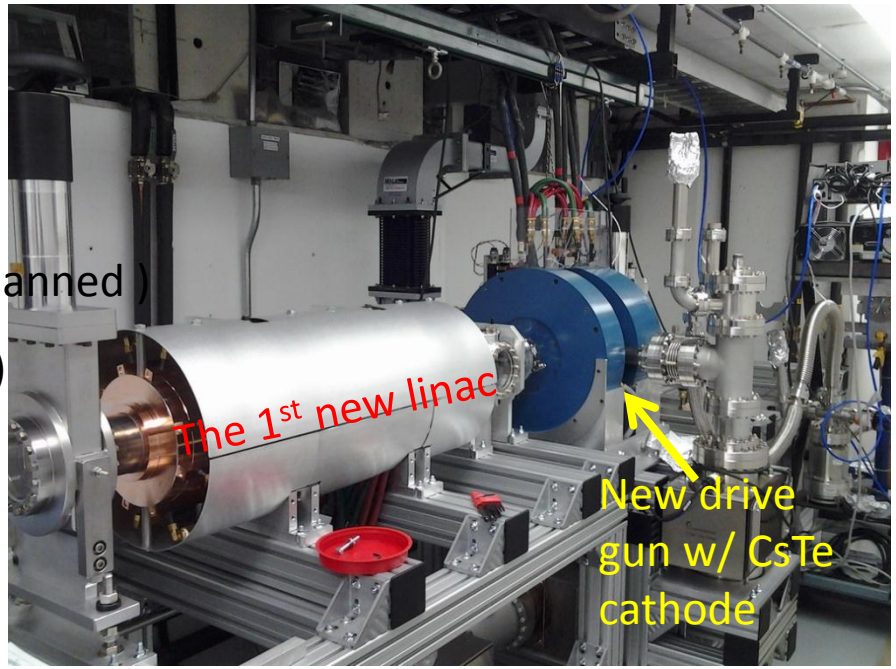

## Selected results in the past 5 years:

- 100MV/m short pulse in an X-band DWA (dielectric wakefield accelerator)
- 50MW short pulse in C-band DWPE (dielectric wakefield power extractor); 20 MW in K-band
- 300MV/m short pulse in a K-band diamond based DWA.
- Enhanced transformer ratio (R=3.4) achieved in a collinear wakefield acceleration

# AWA Facility – Projected operation in 2013: 75 MeV Drive Beam+ 15MeV witness beam (thanks for DoE $2M upgrade fund)

## Basic parameters for the drive beam:

- 1.3GHz Photogun w/ CsTe cathode
- 75 MeV, 1 – 100 nC (reached 150 nC)
- 1~2.5 mm bunch length (a bunch compressor is planned )
- Normalized emittance < 200 mm mrad (at 100 nC)
- Bunch train operation: 32 X 30nC or 10 X 100nC
- Beam power: 3GW or 10GW

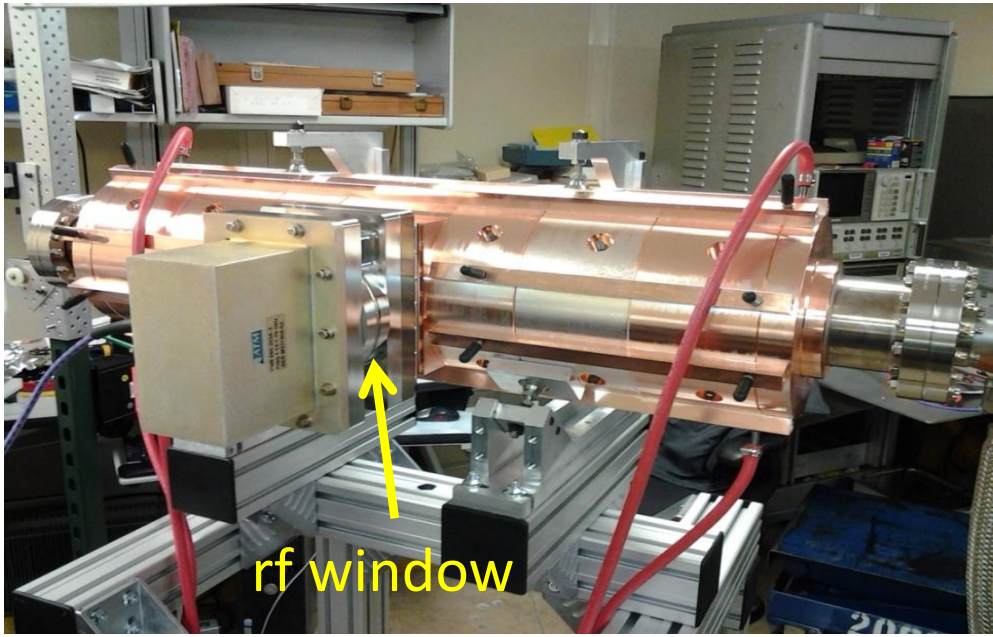



## Experiments forecast in 5 years:

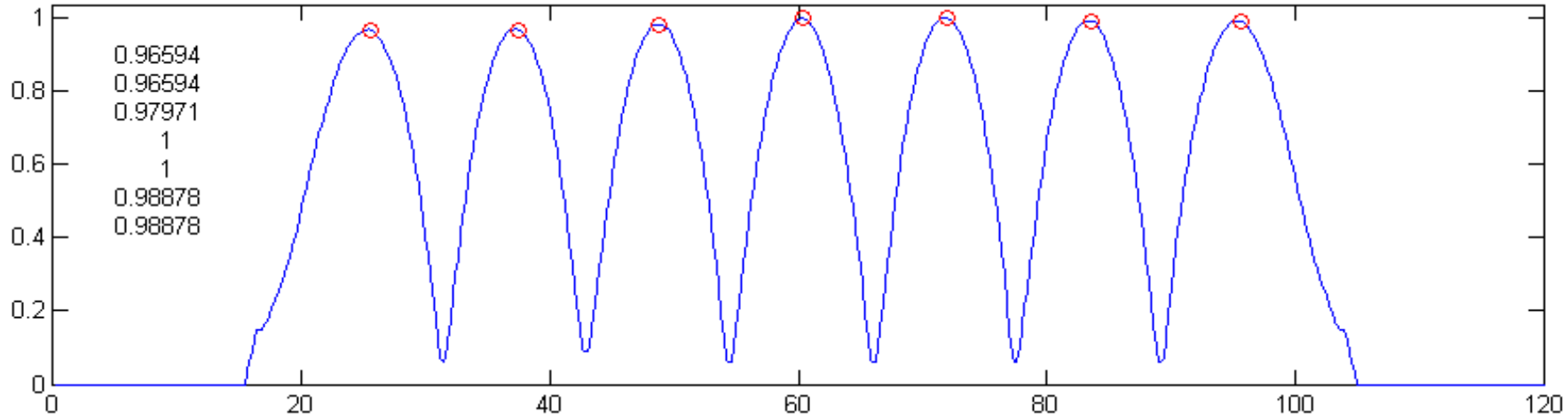
- High power rf generation: 0.1~1GW, ~20ns duration, frequency covers cm to mm wave.
- Two beam acceleration: >200MeV/m energy gain (short rf pulse, ~20ns).
- Collinear wakefield acceleration: >300MeV/m energy gain.
- Bunch shaping to improve efficiency for collinear wakefield acceleration

# New Linac Tanks

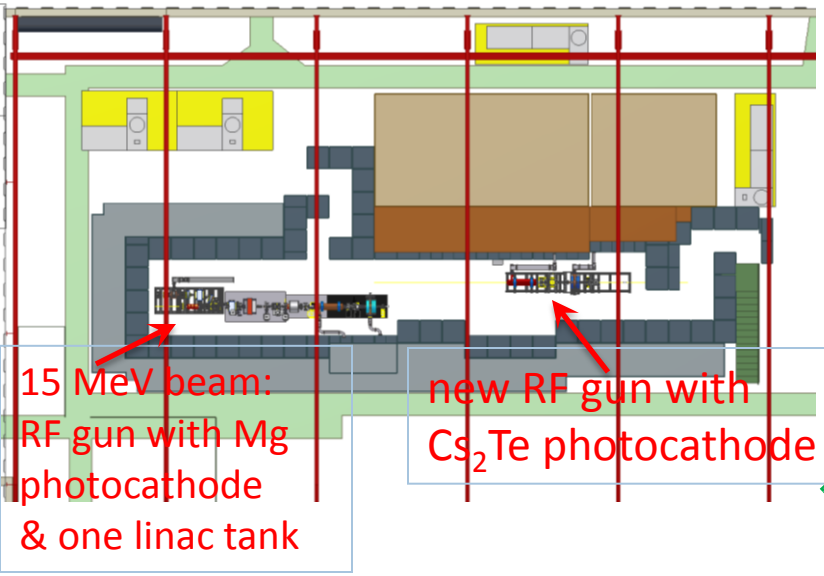
- **rf cavity was acceptable out of the box.**
  - initial $f_0$ = 1299.637 MHz
  - final $f_0$ = 1300.000 MHz (@20.4 $^0$C)
  - initial field balance > 93%
  - $Q_0$ = 25000 (25147 design)
  - $\beta$ = 1.31 (with 2% of 1.28 design)
  - k = 0.0220 (0.0221 design)
- **vacuum is tight** (passed He leak test)
- **rf window developed by AWA/Euclid**




final beadpull measurement after one round tuning (field balance> 97% )



# AWA - present



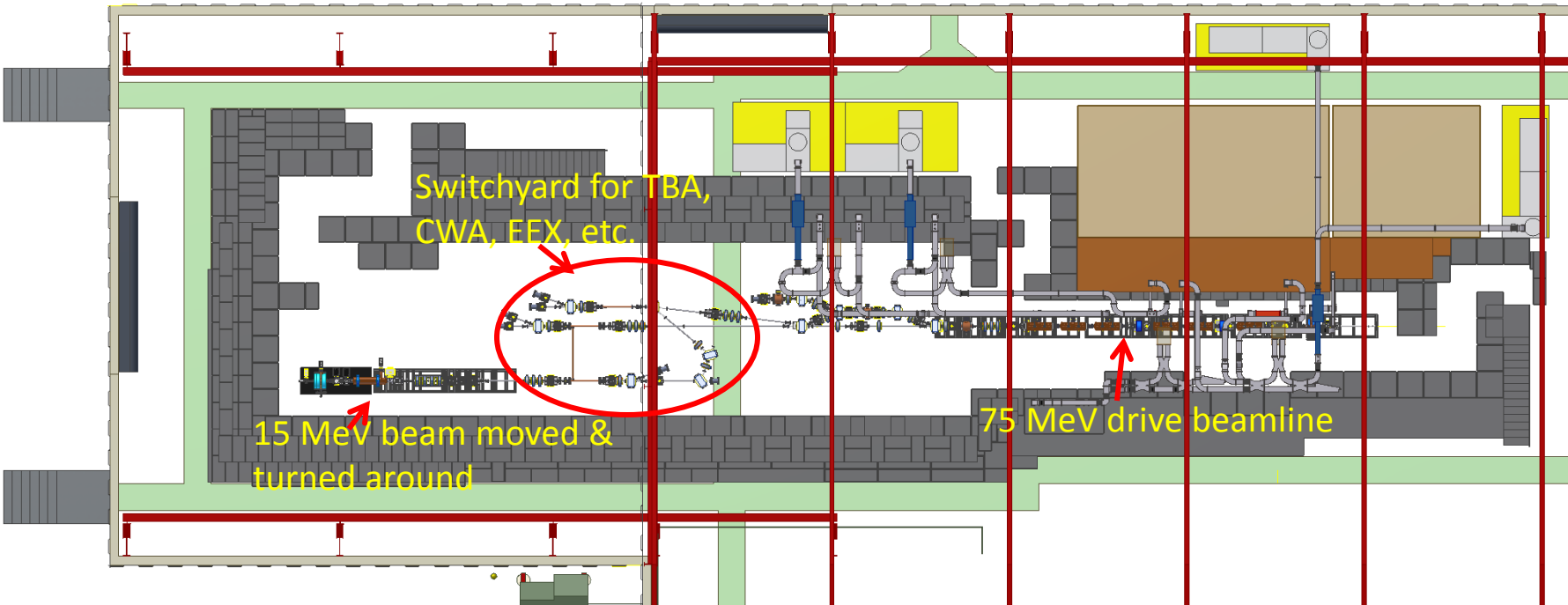

**Key construction in 2012:**

- deliver, install and condition the rest 5 linac tanks
- complete the bunch expansion
- RF distribution system

**Ultimate goal in 2012:**

- **75MeV bunch train generation**

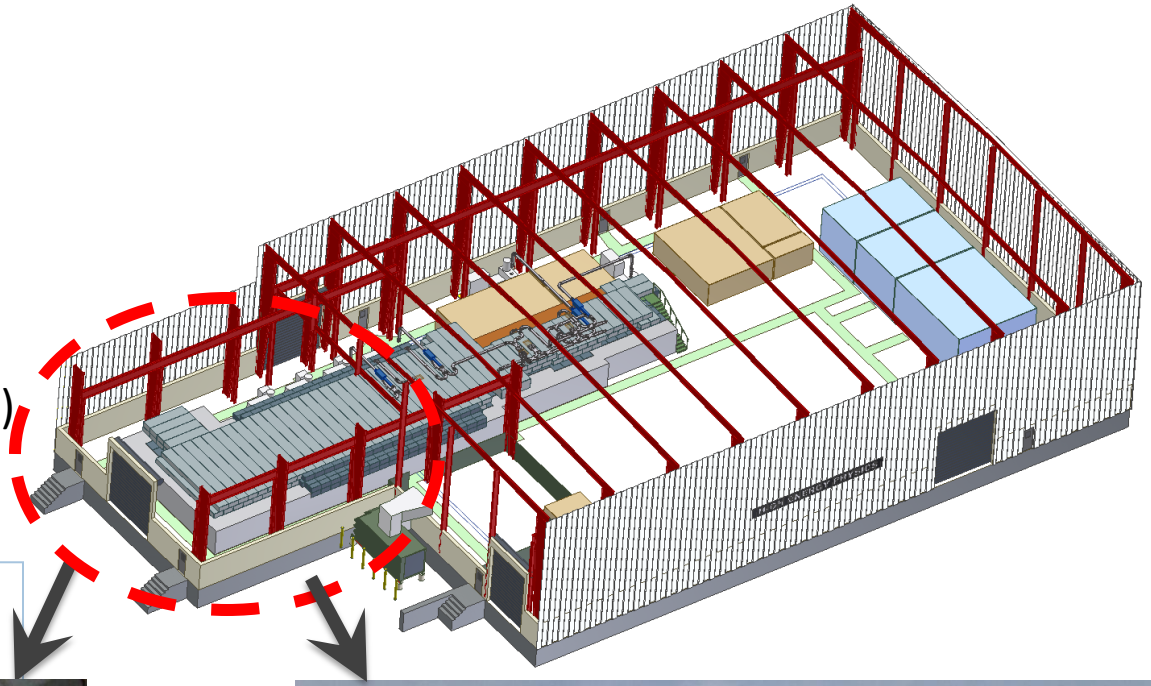
# AWA in 2013



# AWA - Building Expansion (to be completed in June 2012)

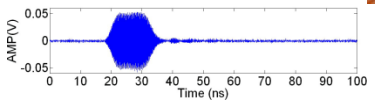
**Thanks to ANL management for $2M+ construction fund:**

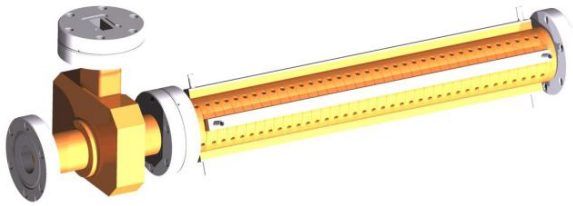
- new annex building (in June 2012)
- new SF6 recovery system (done)
- new cooling water station (done)
- new 1MW power transformer (done)



new annex approx. 60’ x 60’ to house the AWA bunker expansion

# High Power rf Generation by the AWA 75MeV Drive Beam

11.7GHz metallic power extractor is under fabrication at Tsinghua Univ.

Dielectric

| Freq. (GHz) | Aperture (mm) | L (cm) | Q (nC) | σz (mm) | Form factor | Grad. (MV/m) | Power (MW) |
|---|---|---|---|---|---|---|---|
| C-Band (7.8) | 12 | 30 | 100 | 2.5 | 0.92 | 62 | 1107 |
| X-Band (11.7) | 10 | 30 | 80 | 2.5 | 0.83 | 79 | 1012 |
| Ku-Band (15.6) | 8 | 30 | 60 | 2.3 | 0.75 | 88 | 766 |
| K-Band (26) | 6 | 30 | 30 | 1.7 | 0.65 | 75 | 276 |
| W-Band (91) | 2 | 30 | 10 | 1 | 0.16 | 50 | 14 |

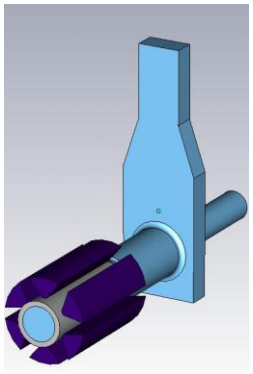
Metallic (2pi/3 mode)

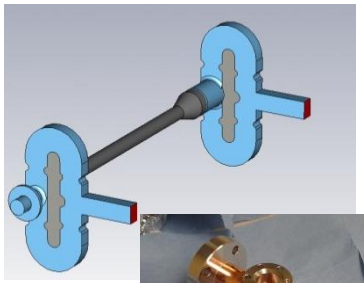
| | | | | | | | |
|---|---|---|---|---|---|---|---|
| X-Band (11.7) | 17.6 | 30 | 60 | 2.3 | 0.85 | 43 | 421 |
| K-Band (26) | 7.5 | 30 | 40 | 2 | 0.55 | 100 | 410 |

# High Gradient Objectives to be Achieved with Upgrades

- Higher gradient excitation: **~ 0.5 GV/m** in long structures.
- Acceleration of witness beam: **~ 100 MeV**
- Higher RF power extraction: **~ GW level**

Example of 26 GHz dielectric loaded structures for two-beam-acceleration experiment:



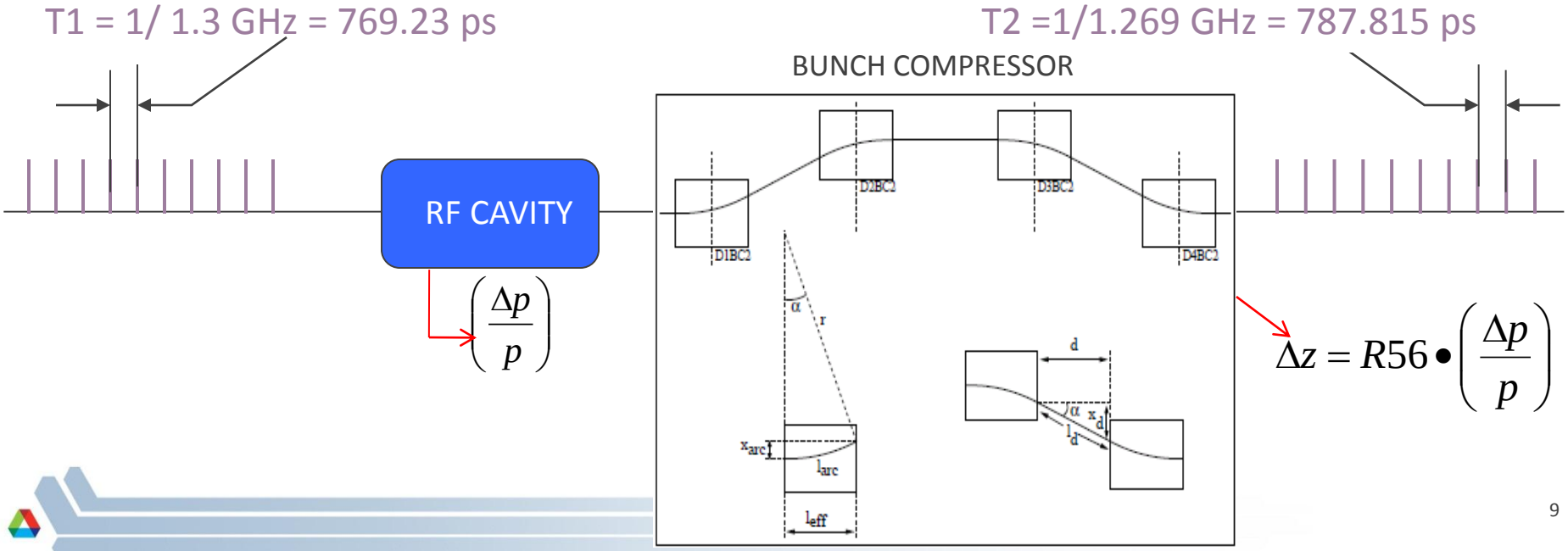


| **Decelerating structure** | **Accelerating structure** |
|---|---|
| ID / OD / length (mm)<br>7.0 / 9.068 / 300 | ID / OD / length (mm)<br>3.0 / 5.025 / 300 |
| Dielectric constant 6.64 | Dielectric constant 9.70 |
| Group velocity 0.254 c | Group velocity 0.111 c |
| R/Q 9.79 kΩ/m | R/Q 21.98 kΩ/m |
| RF power (50 nC) 1.33 GW | Shunt impedance 50.44 MΩ/m |
| Peak gradient 167 MV/m | $E_{acc}$ (1.26 GW) 316 MV/m |
| Energy loss 20.5 MeV | $E_{loaded}$ (1.26 GW) **267 MV/m** |

# New AWA Serve High Gradient Community

- Collinear wakefield acceleration with an independent witness bunch and remotely controlled delay will provide a great platform in a general wakefield measurement of various structures.
- With some efforts, we can slightly adjust bunch spacing to adapt to application of other frequency of interest.

e.g. : the 9th harmonic of the AWA drive beam is 11.7 GHz; it can be retuned to operate 11.424 GHz.



# Closing Remarks

The new 75 MeV drive beam at the AWA Facility will provide exceptional capabilities for the study of RF power generation.

The development and testing of high gradient structures can greatly benefit from the availability of this new drive beam and RF power source.

The new beamline switchyard and “generous” space available for new experimental setups makes the facility flexible and efficient.

Collaborators are welcome!