Argonne Wakefield Accelerator (AWA): a Facility for the Development of High Gradient Accelerating Structures and Wakefield Measurements

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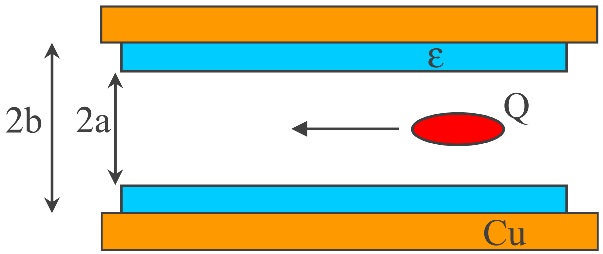
Research at the AWA Facility

Developing accelerator technology for future HEP machines and other applications.

Desirable characteristics:

- High gradient acceleration (compact)
- Relatively low cost
- Modular (stages)
- Works for electrons and positrons
- Macroscopic beam apertures
- Microwave range of frequencies
- Explores the use of advanced materials

Wakefields in Dielectric Structures (a short Gaussian beam)

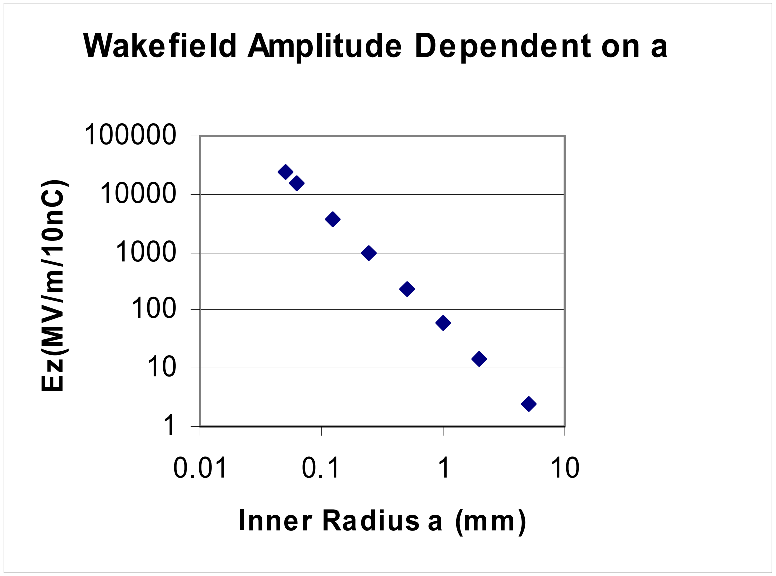


$$W_Z(z) \approx \frac{Q}{a^2} \exp\left[-2\left(\frac{\pi\,\sigma_z}{\lambda_n}\right)^2\right]\cos(kz)$$

$$\sigma_r = \left(\frac{\varepsilon_N}{\gamma}\beta\right)^{1/2}$$

AWA approach:

- High charge drive bunches
- High gradient
- Short RF pulses
- Macroscopic beam apertures
- Microwave frequencies (8 – 26 GHz)



Reasons for Recent AWA Upgrades

Have two beam accelerator capability:

Have two parallel beamlines, allowing drive bunches to excite wakefields and accelerate witness bunch.

Use the demonstrated high gradients to accelerate beam:

The high quality drive beam has excited high gradient accelerating fields (100 MV/m) in dielectric loaded structures. Now these high gradients will be used to accelerate a witness bunch.

Have higher drive beam energy for high gradient and sustained acceleration:

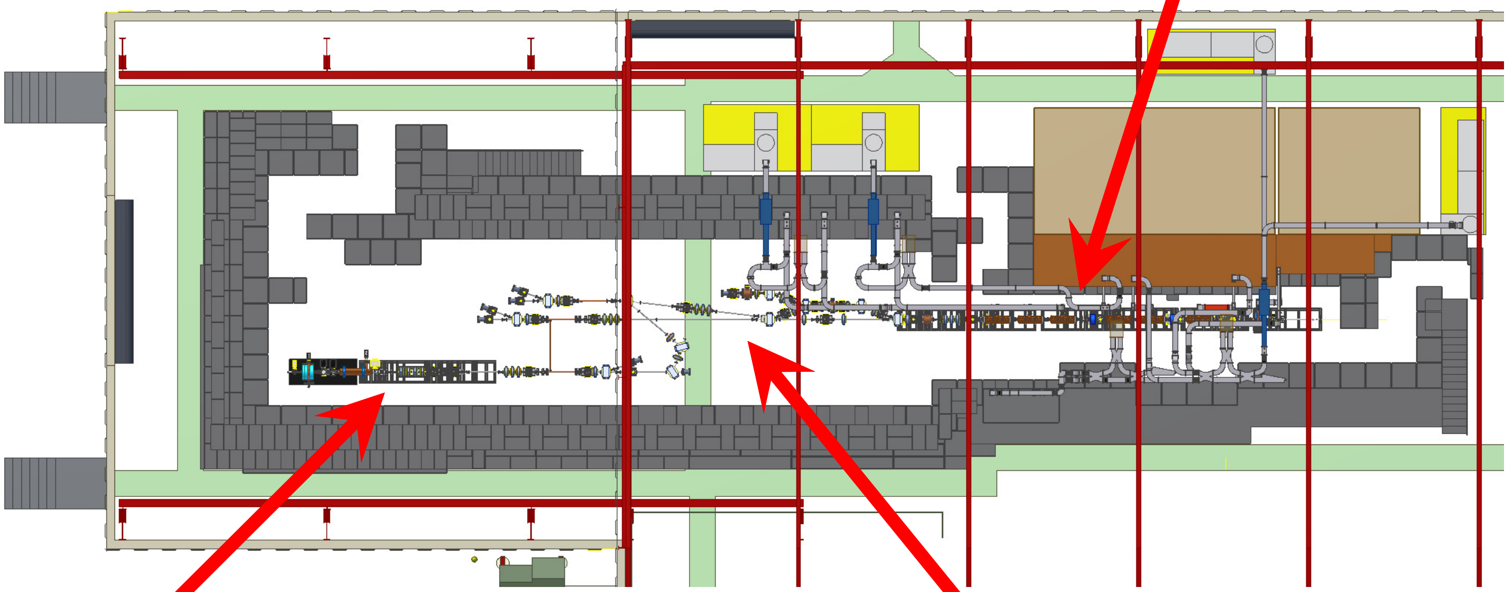
- Propagation of drive beam through smaller diameter structures, resulting in even higher accelerating gradients.
- More energy available in drive bunches, allowing extraction of higher energy RF pulses.
- Construction of longer structures will demonstrate higher energy gain.

Have beamline switchyard for added flexibility:

Beamline switchyard will greatly facilitate the implementation of distinct experimental setups: collinear wakefield acceleration, two-beam-acceleration, phase space manipulation and, further into the future, staging.

AWA Facility

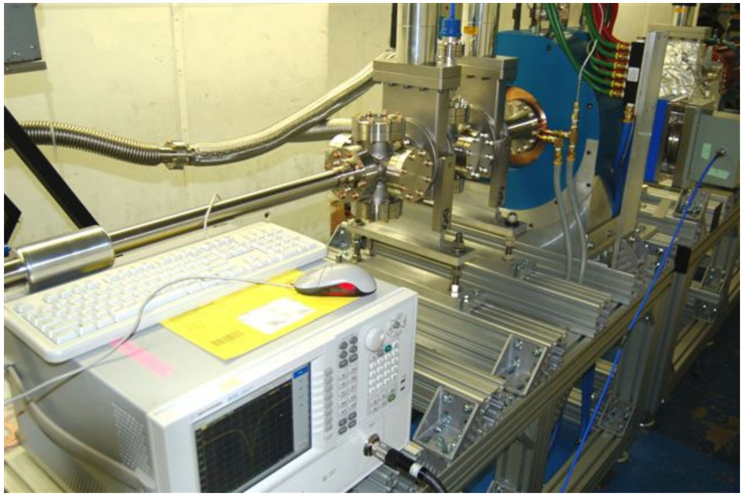
75 MeV drive beam:
RF gun with Cs_2Te photocathode
& six linac tanks



15 MeV witness beam:
RF gun with Mg photocathode
& one linac tank

Beamline switchyard
(under construction)

New RF Gun with Cesium Telluride Photocathode



New RF gun installed in AWA bunker:

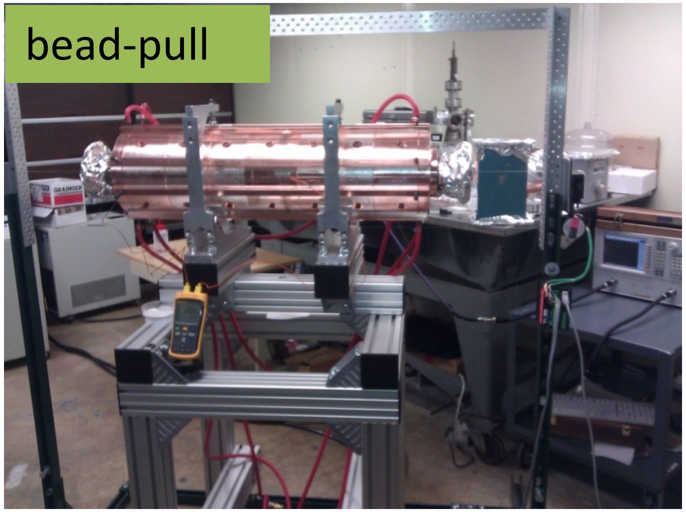
- 1 ½ cell, L band (1.3 GHz)
- 12 MW, 80 MV/m on cathode
- RF conditioned to 15 MW with Cu photocathode
- Generated beam (single bunches) from Cu and Cs_2Te cathodes

Cesium Telluride preparation chamber:

- necessary QE ~ 1%
- routinely achieving QE > 10%

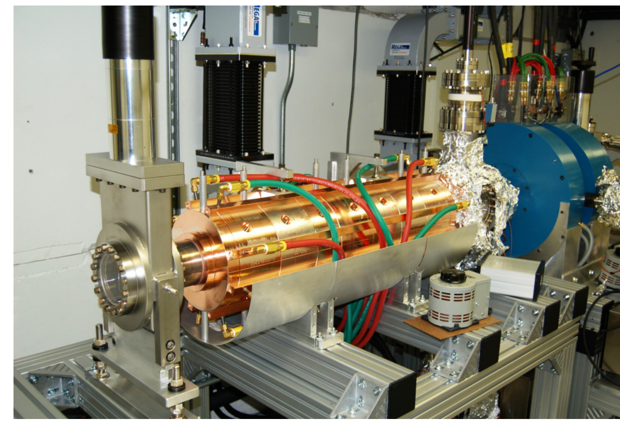
New Linac Tanks

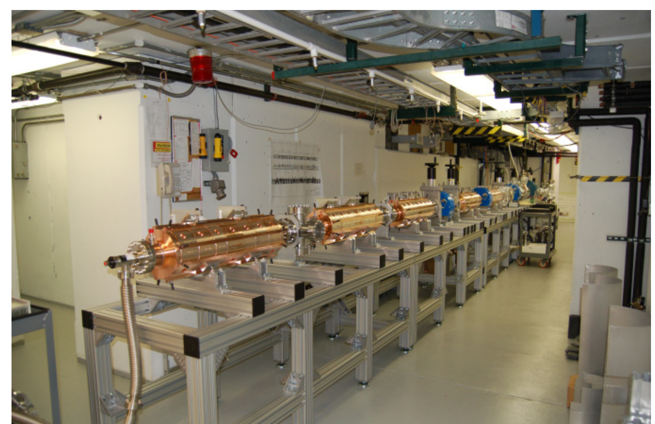
- 7 cell π mode, L band (1.3 GHz)
- 10 MW, 11.2 MeV energy gain
- Q = 26687
  Shunt = 20.6 Mohm/m
  R/Q = 773.4



- Turnkey fabrication, directly from design to finished cavity
- Designed by ANL/SLAC
- Fabrication by local vendor (Hi Tech)
- Tuned and balanced at Argonne
- Adopted by LBL for the NGLS APEX test beam

Gun and first linac tank

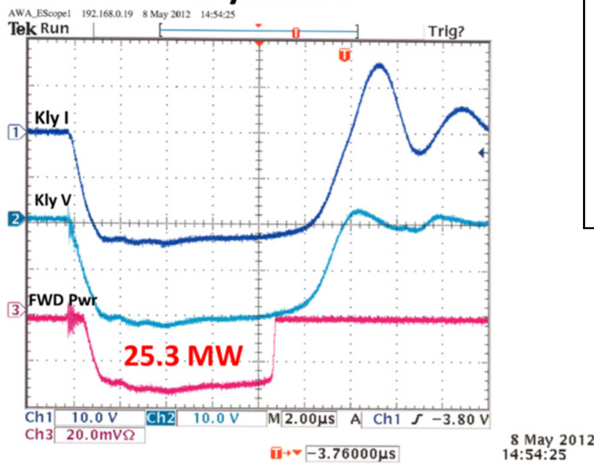




Gun and six linac tanks

Additional 80 MW of RF Power (three klystrons)

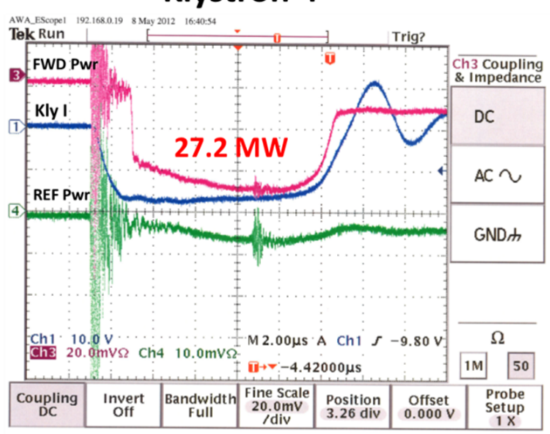
Klystron 3



Two new Thales TV 2022X

- L band (1.3 GHz)
- 10 μs, 25 MW

Klystron 4



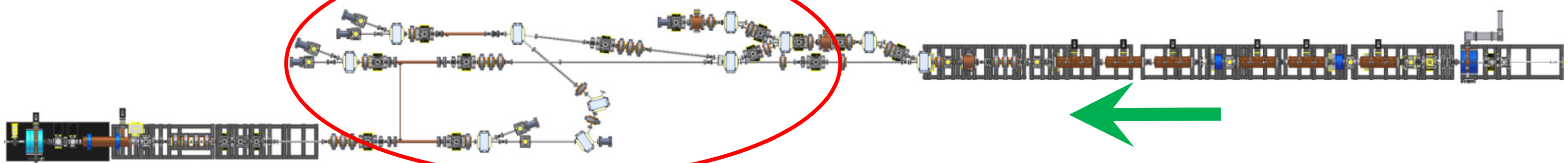
30 MW Litton klystron on loan from LANL (thanks to B. Carlsten and S. Russell)

Overview of AWA Beamlines

experimental area

collinear & TBA

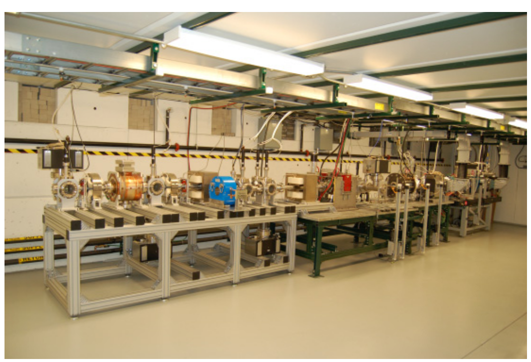
EEX & bunch compression



witness beam U-turn

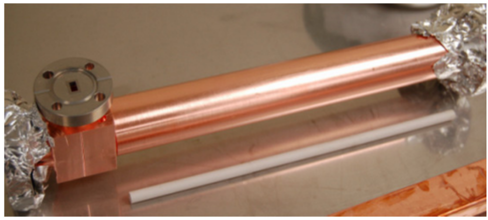
75 MeV drive beam

15 MeV witness beam

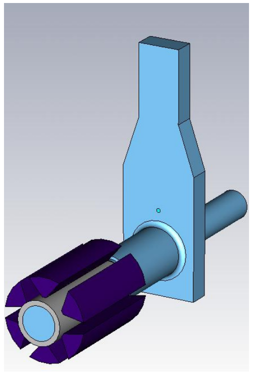


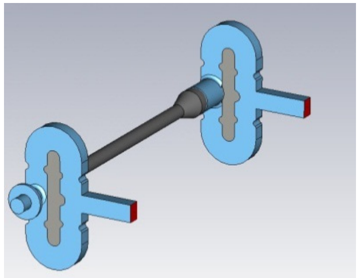
Objectives to be Achieved with Upgrades

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



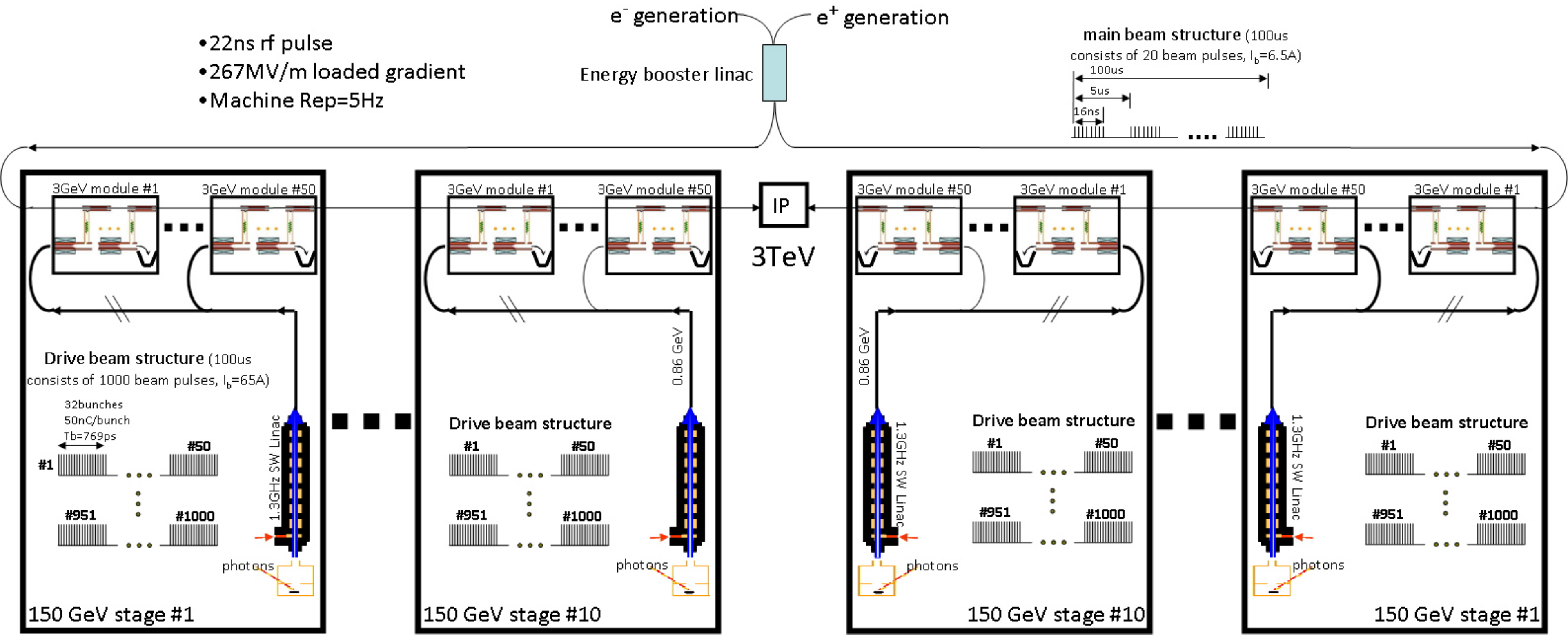
Example of 26 GHz dielectric loaded structures for two-beam-acceleration experiment:



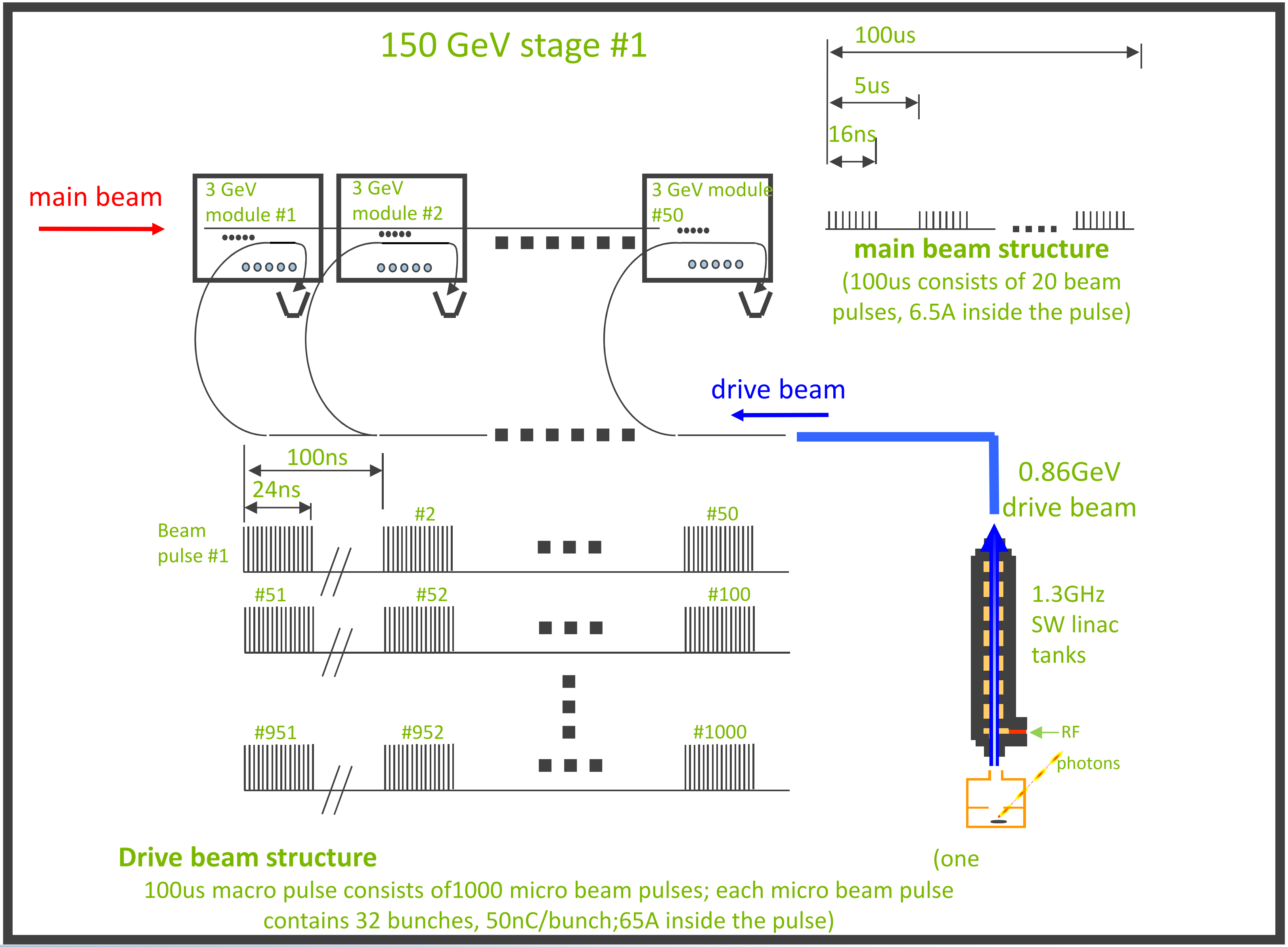


Decelerating structure	Accelerating structure
ID / OD / length (mm) 7.0 / 9.068 / 300	ID / OD / length (mm) 3.0 / 5.025 / 300
Dielectric constant 6.64	Dielectric constant 9.70
Group velocity 0.254 c	Group velocity 0.111 c
R/Q 9.79 kΩ/m	R/Q 21.98 kΩ/m
RF power (50 nC) 1.33 GW	Shunt impedance 50.44 MΩ/m
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**

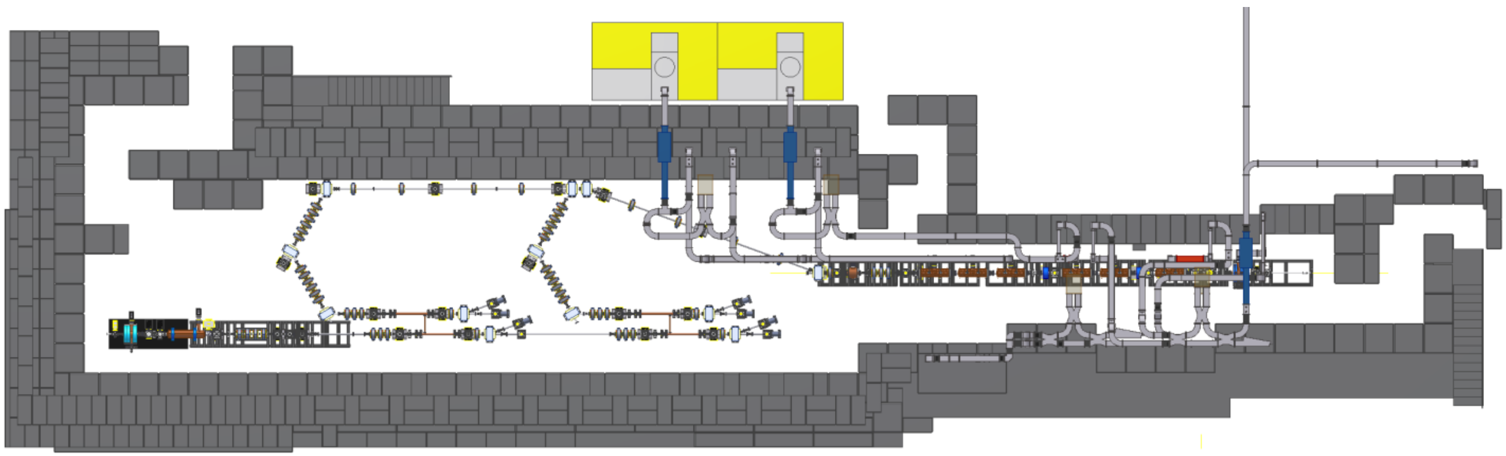
Layout of the ANL 26GHz 3TeV Flexible Linear Collider

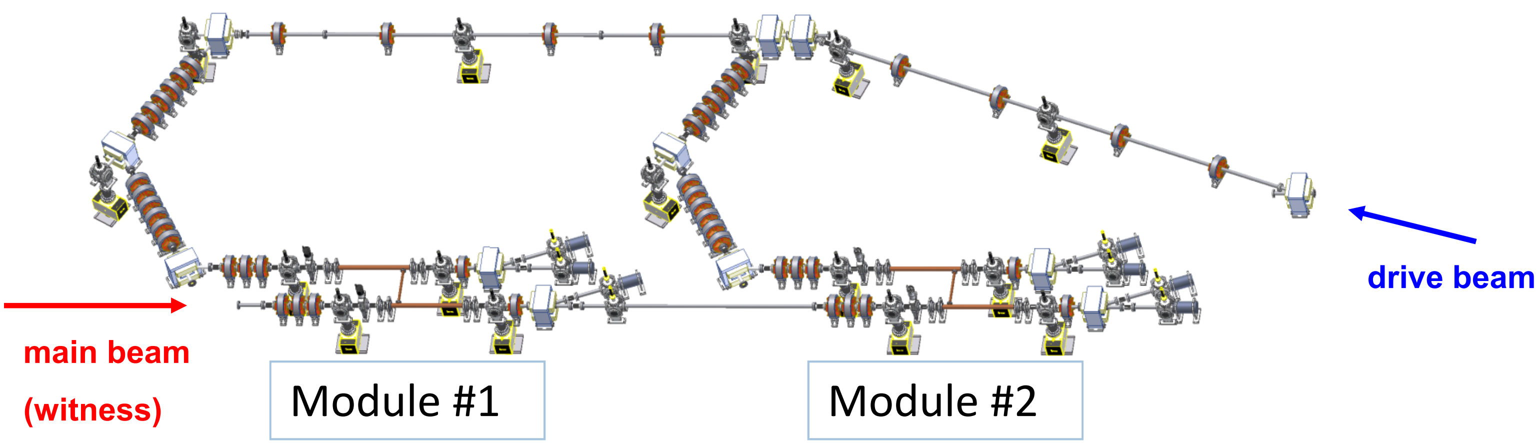


Summary of a 150 GeV Stage

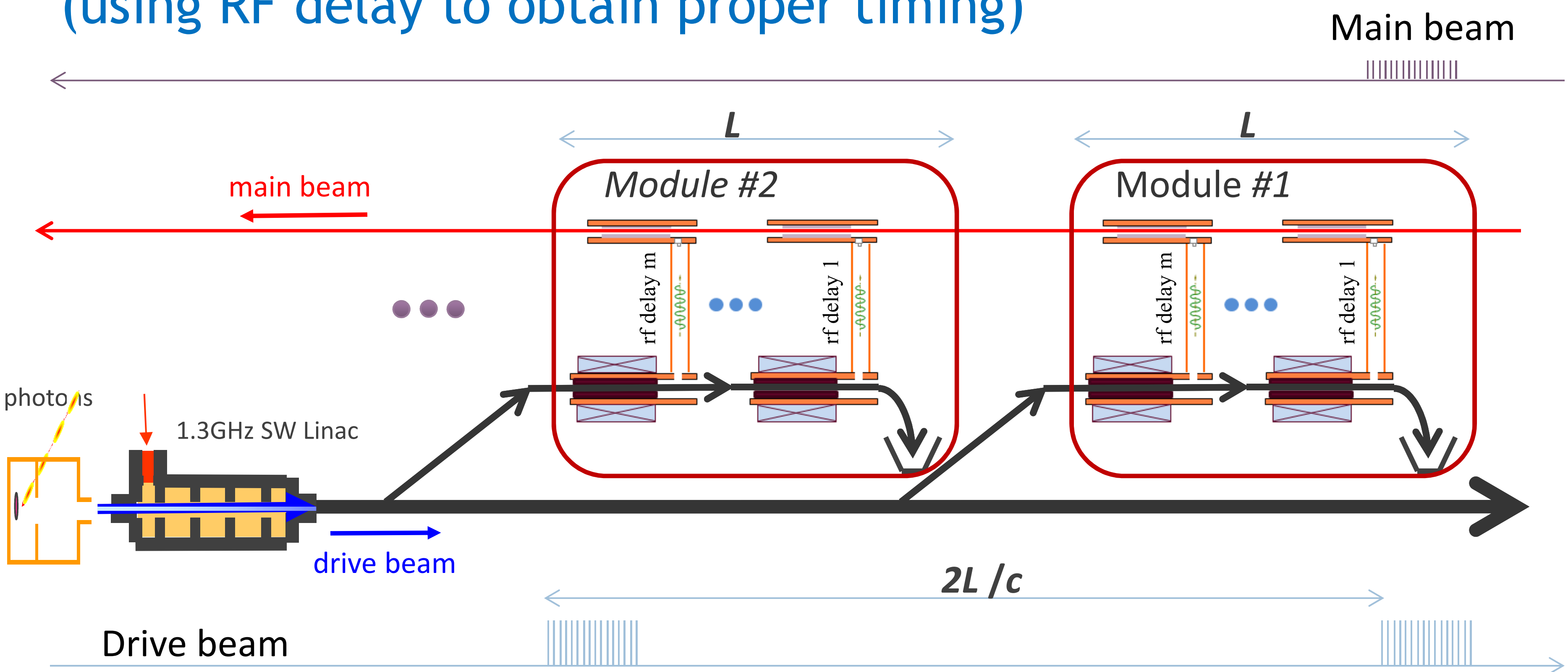


Longer Term Goal at AWA: Staging





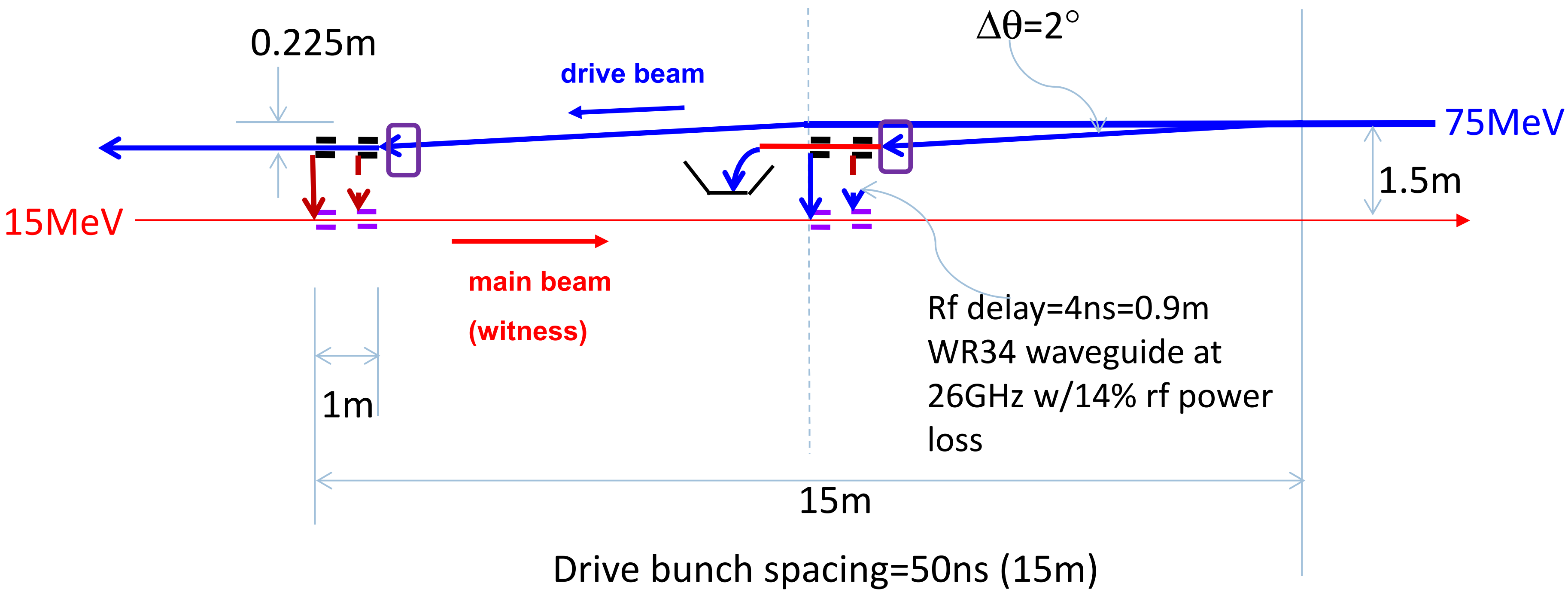
New scheme to avoid drive beam U-turn (using RF delay to obtain proper timing)



rf delay1=0;
rf delay2=$2L_s/c$;
rf delay m=$2*(m-1)*L_s/c$,
m is the # of structures in each stage,
L_s is the length of a single structure.

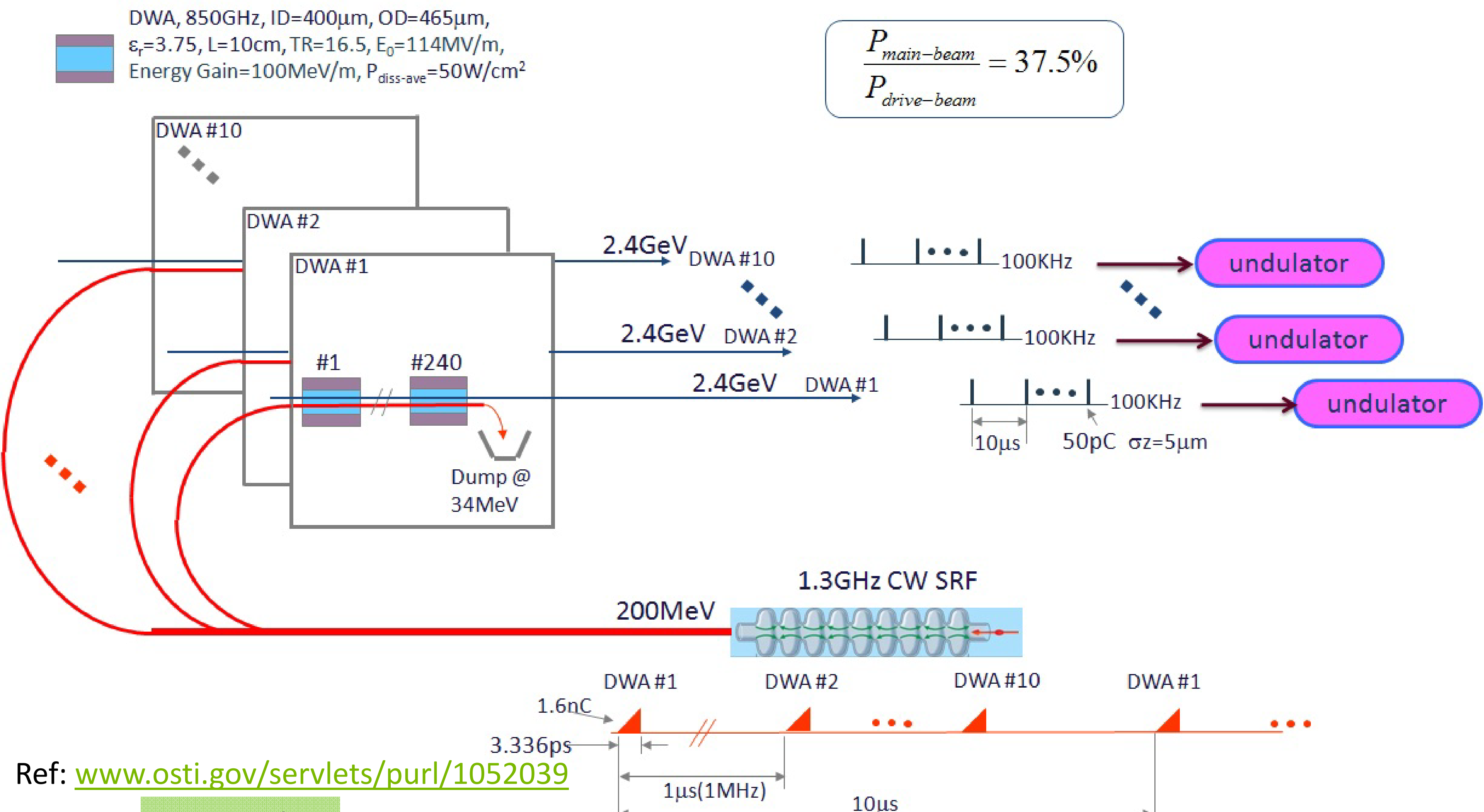
Example: Using parameters in the original design, we have 38 30cm-long structures in one module; then the shortest delay is 2*0.3*m* /*c*= **2*ns***; the longest delay is 2* (38-1)*0.3*m*/*c* =***74ns.***
In order to reduce rf losses in the delay line, let's consider the most commonly used circular overmoded waveguide w/ TE01 mode (air filled, copper wall, a=0.7", f=26GHz): **delay=3.6ns/m; power loss=0.22%/m**
Then the longest delay line is 74ns/3.6ns=**20.6m**
The rf loss is 0.22%*20.6=**4.5%**

AWA Staging Demonstration



p_0 (MeV/c)	$\Delta\theta$ (mrad)	$\Delta p_\perp$ (MeV/c)	T_{rise} (ns)	TW Deflector Power, Length
75	34.9	2.62	50	29.6MW, 0.3m

Technology for HEP machine also have great impact in other applications: e.g. Dielectric wakefield accelerator to drive future FEL (100MeV/m, 100kHz Rep.)



Ref: www.osti.gov/servlets/purl/1052039

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Conclusion

Commissioning of the upgraded AWA Facility is underway.

The new drive beam will enable the generation of high gradient wakefields (hundreds of MV/m) and the demonstration of significant acceleration of the witness beam (~ 100 MeV).

The demonstration of staging will soon follow.

THANK YOU FOR YOUR ATTENTION!!